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This presentation displays analysis of performed propagation measurements, including measurement goals and capabilities, sample results, and model comparisons.

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Presentation given at the IEEE Joint Signal Processing and Communications Society Meeting, San Diego State University, May 26, 1999.

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transmitter antenna

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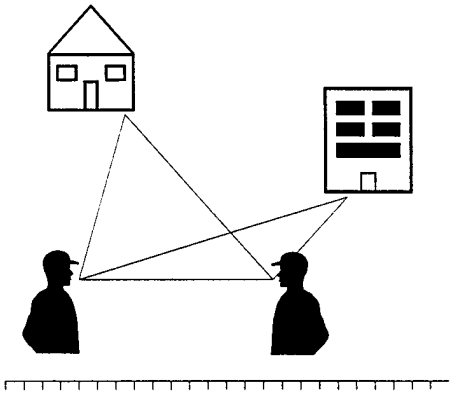
Wireless Propagation Measurements, Analysis, and Modeling



SSC-SD D855

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Outline

- Measurement Goals and Capabilities
- Multipath Tutorial
- Sample Results
  - Urban Channel
    - HMMWV Motion
    - Human Mount w/Motion
    - Various Antenna Heights
  - Many Channels
    - Path Loss vs. Delay Spread
- Model Comparisons

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SSC-SD Measurement Goals

- Measure Channel Responses
  - Urban/Suburban, Hills/Trees, Airfield
  - Antennas close to buildings
  - Antennas mounted on humans in motion
  - Low antenna heights
  - VHF, UHF, ISM, LBand
- Compare w/existing Propagation Models

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Measurement System Capabilities

- Long Duration (25s)
- High Resolution (12m)
- Long Range (10km)
- Frequency Versatile (30MHz-2GHz)
- Severe Environments (Heavy Urban)
- Arbitrary Waveform Capability

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Data Applications

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- Propagation Science
- Radio Design
  - Algorithm development/testing
  - Waveform development/testing
  - Antenna development/testing
  - Transmit power selection/power control design
  - Frequency and BW selection
  - Computation update requirements
- Network Modeling
- Network Design

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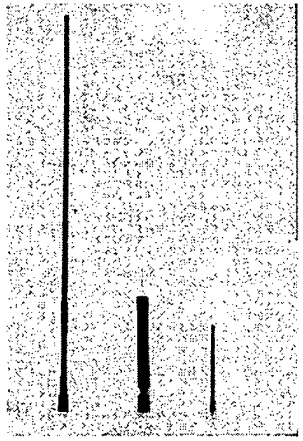
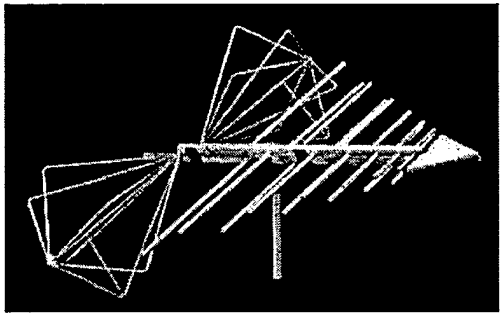
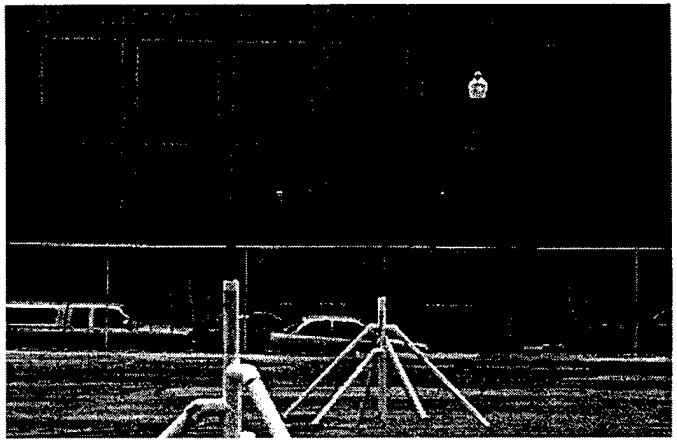
Transmitter/Receiver

Transmitter Antennas





Receiver Antennas



HMMWV w/AC Power for Transmitter

Navy Van for Receiver Equipment

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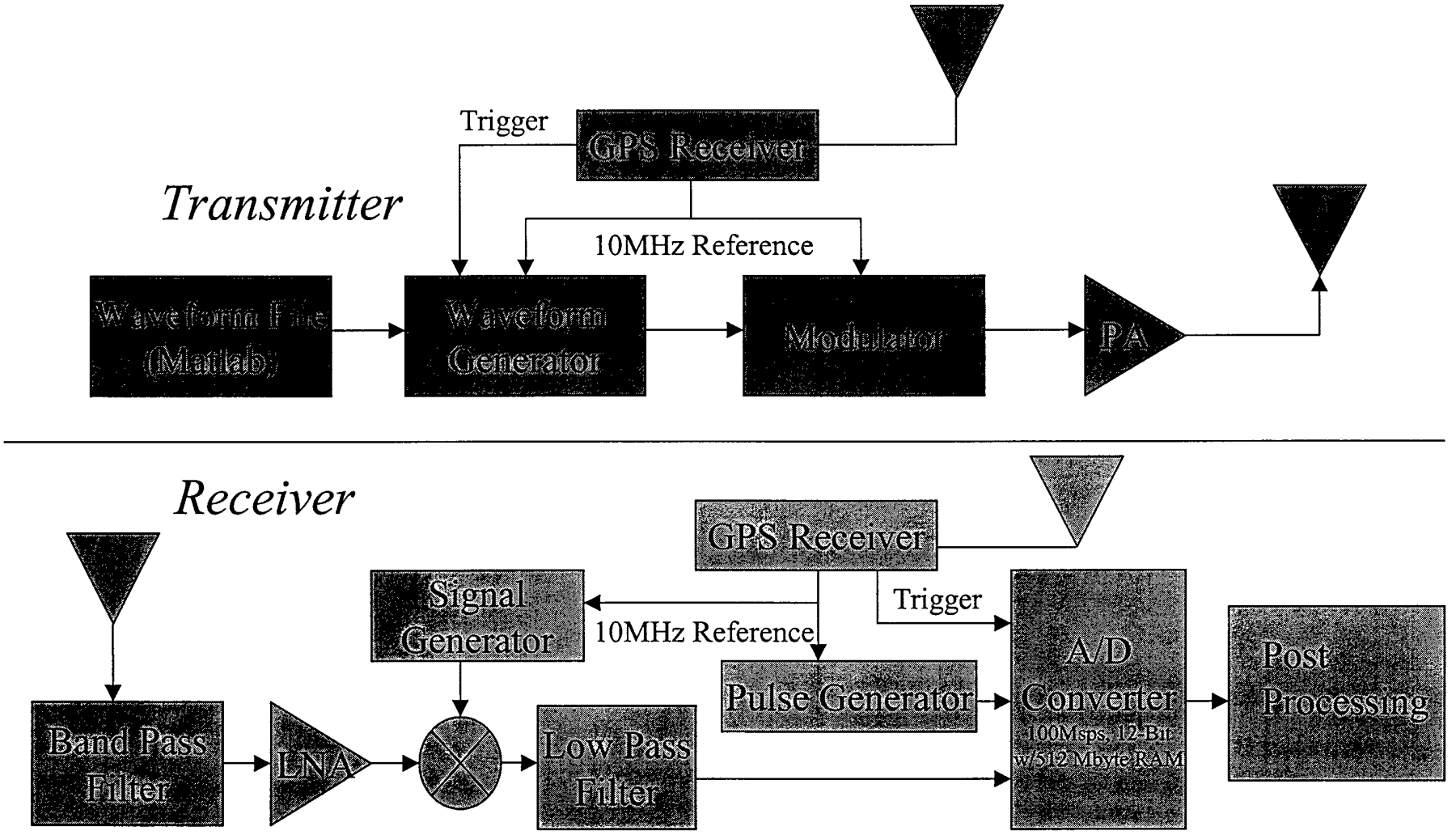
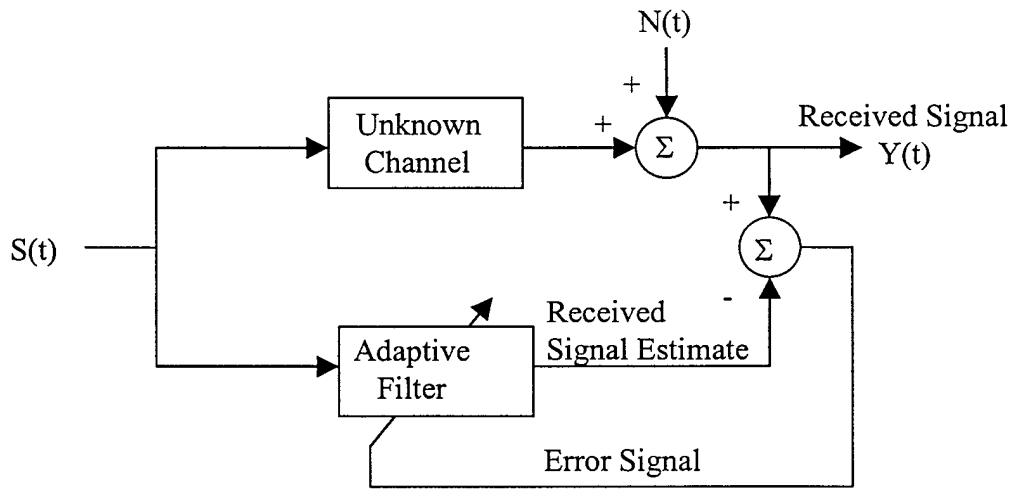
Propagation Testbed

30MHz-2GHz



Adaptive Channel Estimation

- Channel Modeling Algorithm:



- Adaptive FIR Channel Estimation Filter:
  - 3 Phases:
    - Acquisition - Recursive Least Squares (RLS)
    - Training - Normalized Gradient Decent (NLMS)
    - Tracking - Normalized Gradient Decent (NLMS)
  - Filter Tap Length - 240 Taps

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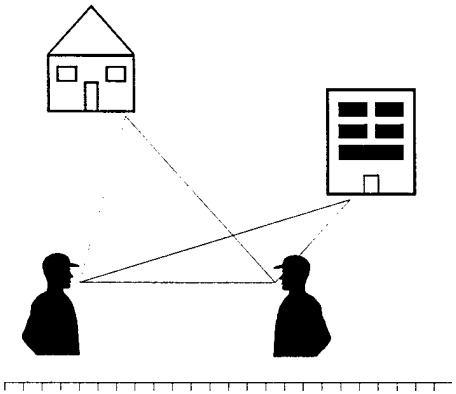
Multipath



- Exact solution: Maxwell's equations and Boundary Conditions
- Approximate solution: Trace rays using geometric optic rules
- Better: Add edge diffraction and transmission through wall
- But: Need a good geometrical description of the environment
- Alternative: STATISTICAL DESCRIPTION

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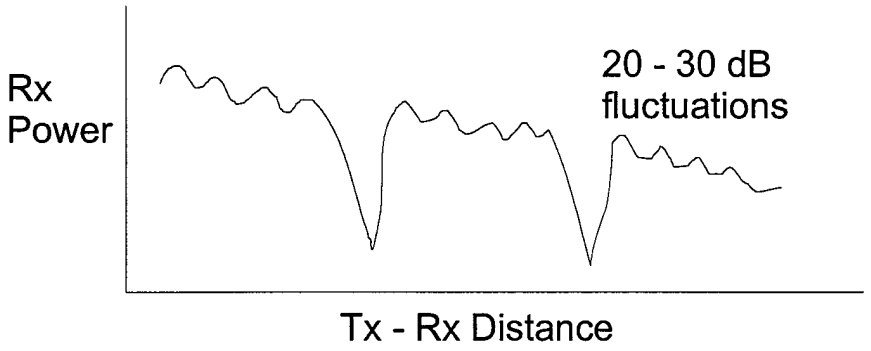
Narrowband Signals

$$p_\tau = p_o \left| \sum_{i=1}^{L} \frac{a_i}{d_i} e^{j\varphi_i} \right|^2$$



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Wideband Signal

$$h(\tau,t)=\sum_{i=1}^{L}\beta_i e^{j\varphi\delta(t-\tau_i)}$$

$$y(t)=\int x(t-\tau')\,h\left(\tau,\tau'^{1}\right)$$

$$=\int x(t-\tau')\sum_{i=1}^{L}\beta_{ie}e^{j\varphi_i}\,\delta(\tau'-\tau_i)d\tau'$$

$$=\sum_{i=1}^{L}\beta_i e^{j\varphi_i}x(t-\tau_i)$$

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Ideal Case (Infinite BW)

$$\text{Let} \qquad x(t) = \delta(t)$$

$$\Rightarrow \quad y(t) = h(\tau, t)$$

$$|y(t)|^2 = y(t)y^*(t)$$

$$= \sum_{i=1}^{L} \sum_{k=1}^{L} \beta_i \beta^*_{ke}{}^{j(t-\tau_i)} \delta(t - \tau_k)$$

$$p = \int |y(t)|^2 dt =$$

$$= \sum_{i=1}^{L} \sum_{K=1}^{L} \beta_i \beta^*_k e^{j(\varphi - \varphi_k)} \int \delta(t - \tau_i) \delta(t - \tau_k) dt$$

$$= \sum_{i=1}^{L} |\beta_i|^2$$

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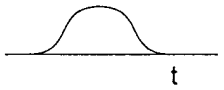
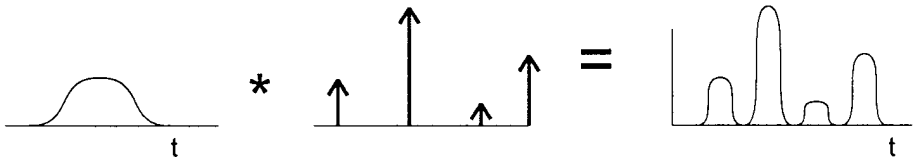
Power Delay Profile
(Practical Case)

x(t)= 

y(t)= 

σ = delay spread

Smearing due to convolution.

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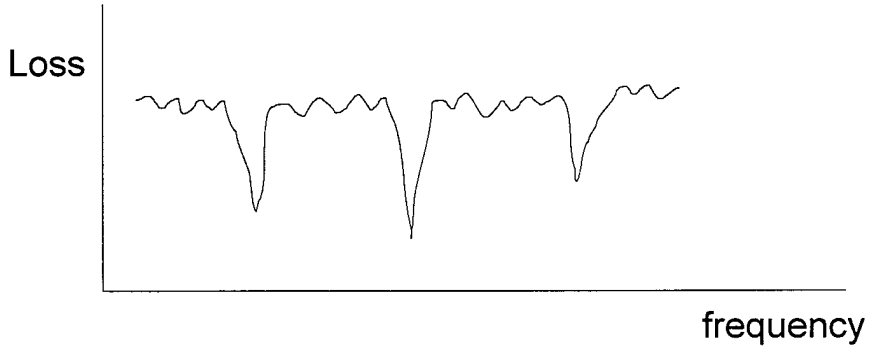
Channel Frequency Response



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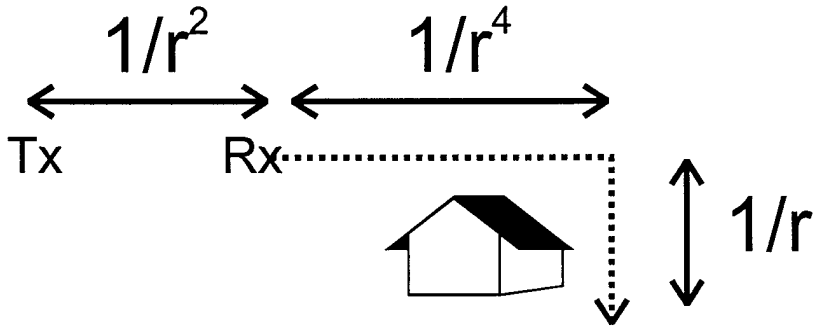
Modeling

- **Path Loss (JTC)**



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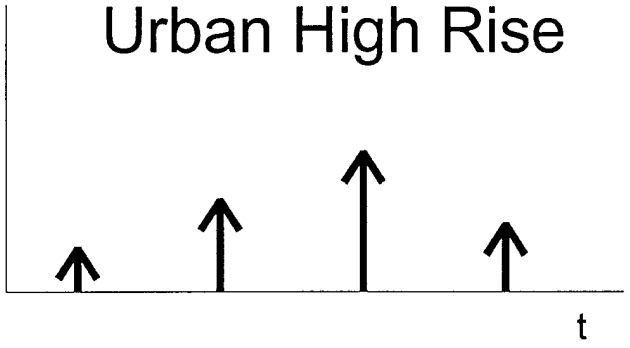
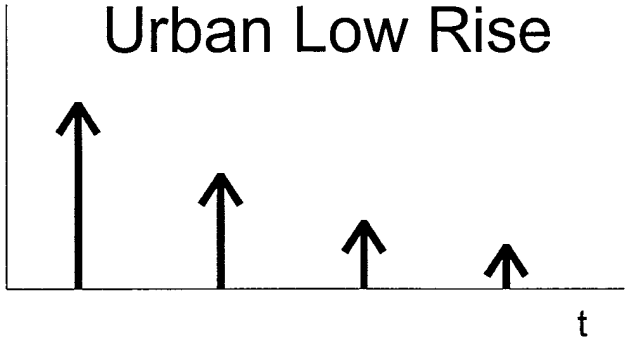
Canonical Tapped Delay Line Model





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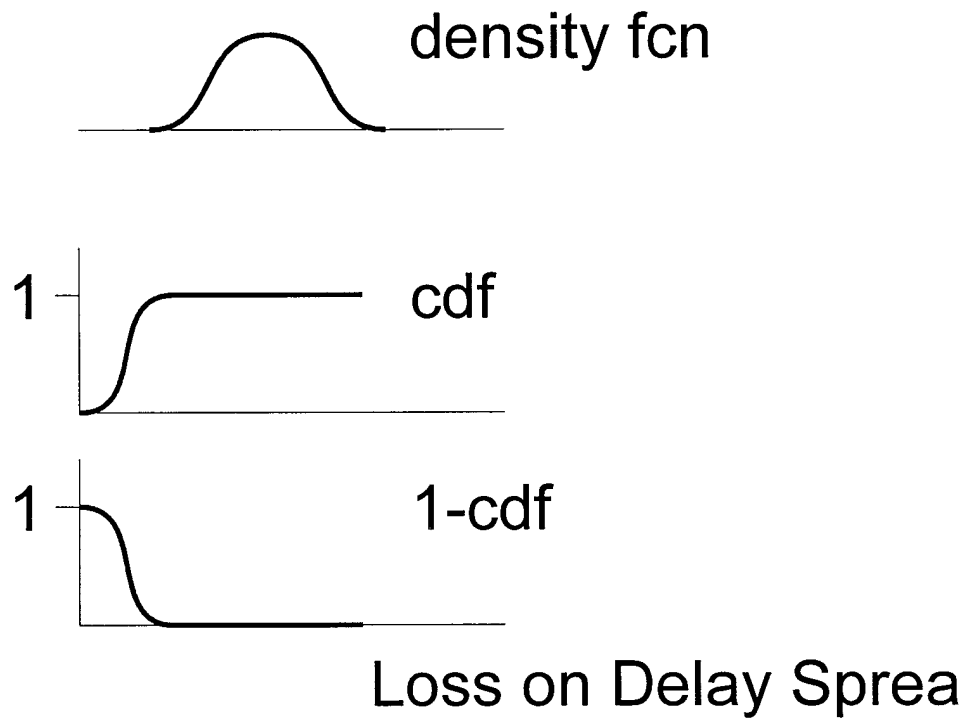
Motion Measurements (8 Sec)

- A collection of channel realization in a single measurement



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Motion Measurements (8 Sec)

- Compute means and
  - 1) Compare to each other
    - different carrier freqs
    - different environments
  - 2) Compare to Models
    - JTC
    - Hata
    - TIREM

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Urban San Diego

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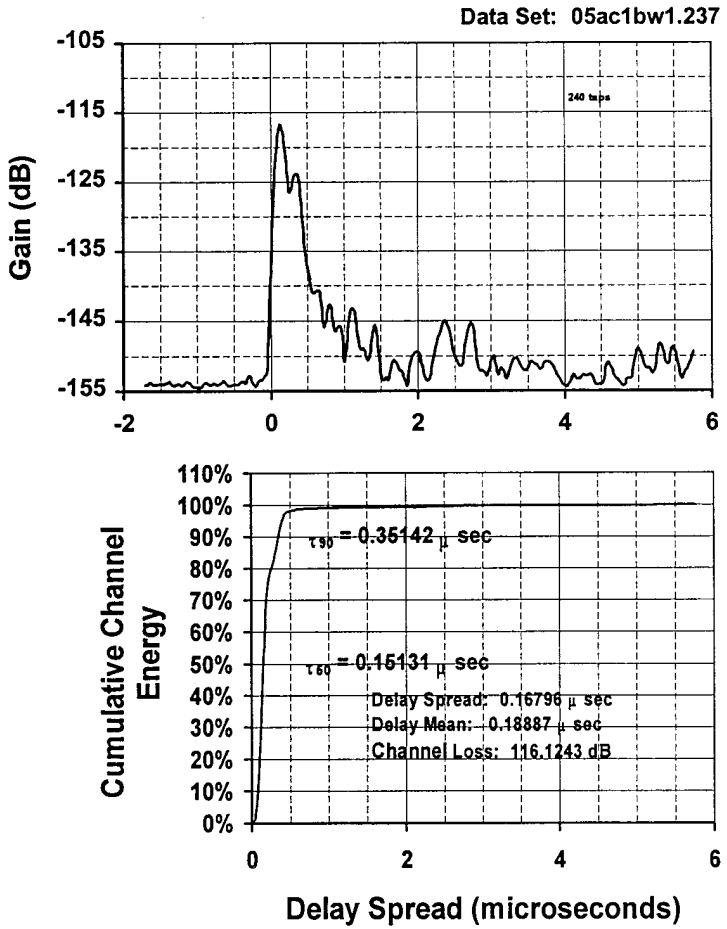
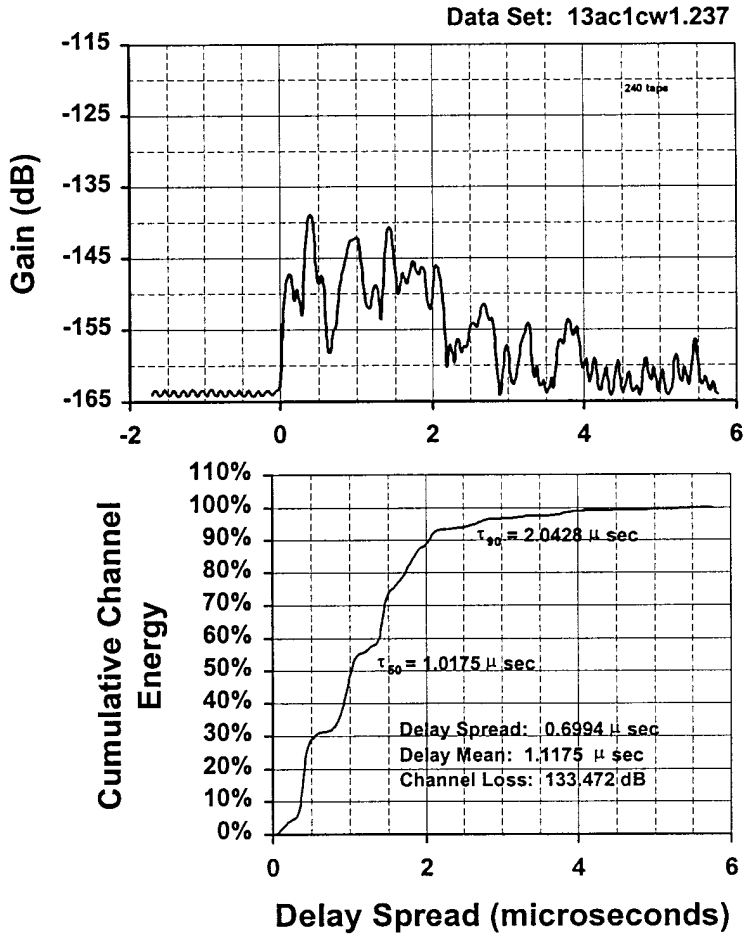
Airfield and Urban Delay Profiles

Airfield
(3.48 km; 237 MHz)



Urban
(2.15 km; 237 MHz)



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Channel Estimates - Motion

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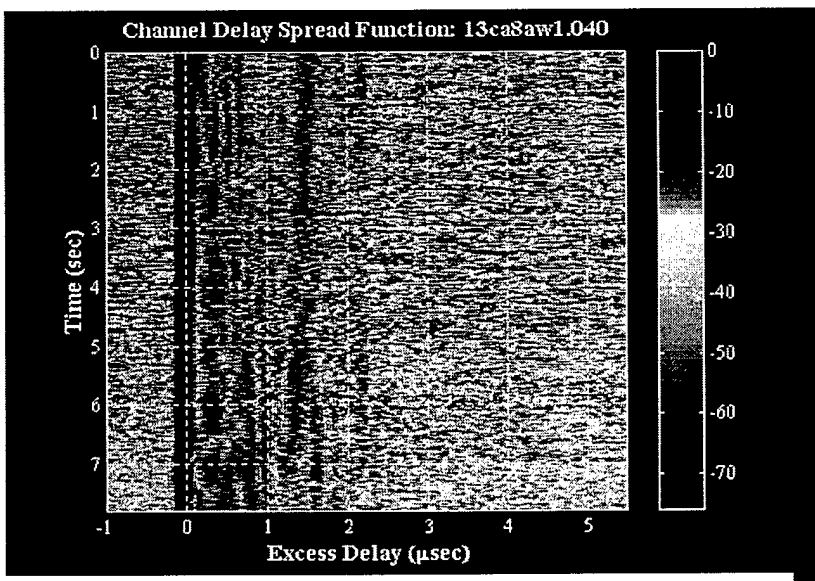

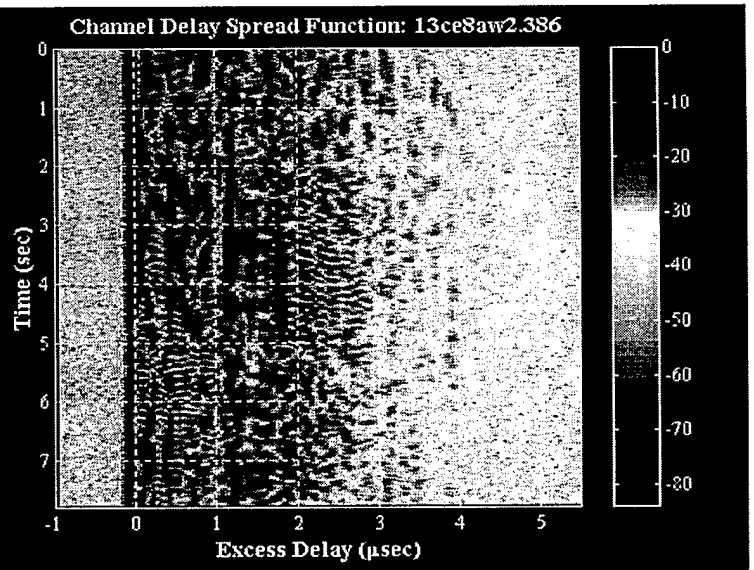

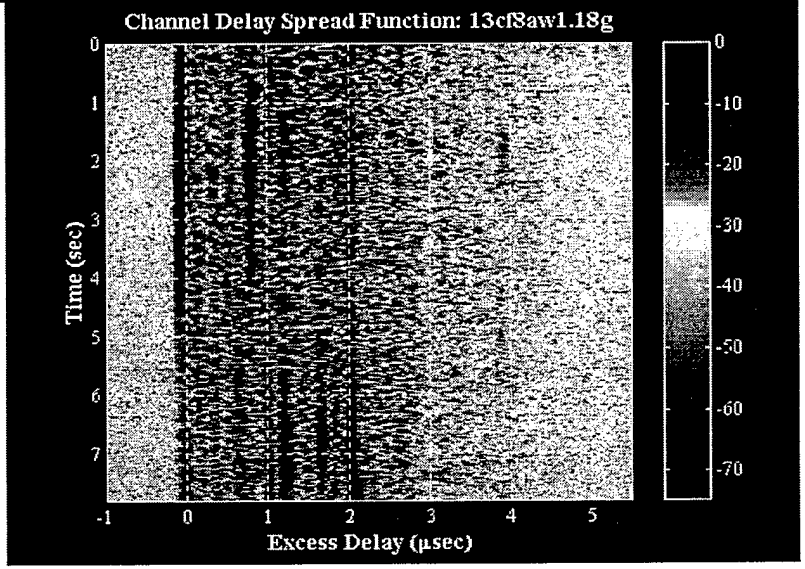

- Speed ~ 4 m/sec
- Environment: Medium/Heavy Urban
- 2 Km Distance
- Low-Low Antenna
- No Line of Sight

- At Lower Frequencies Diffraction Allows "Main Path" to Dominate
- Higher Frequency Channel(s) tend to exhibit greater energy delay

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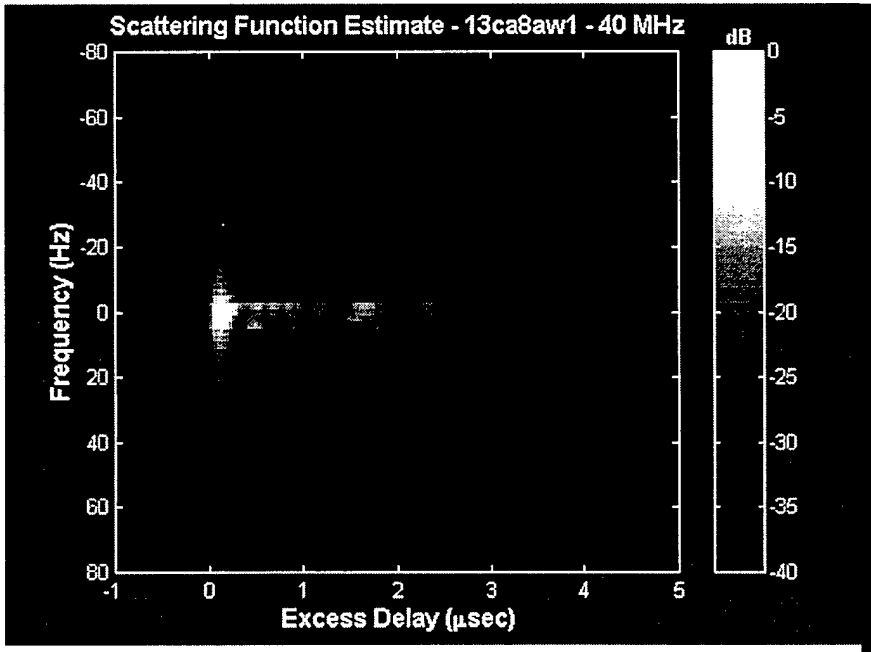
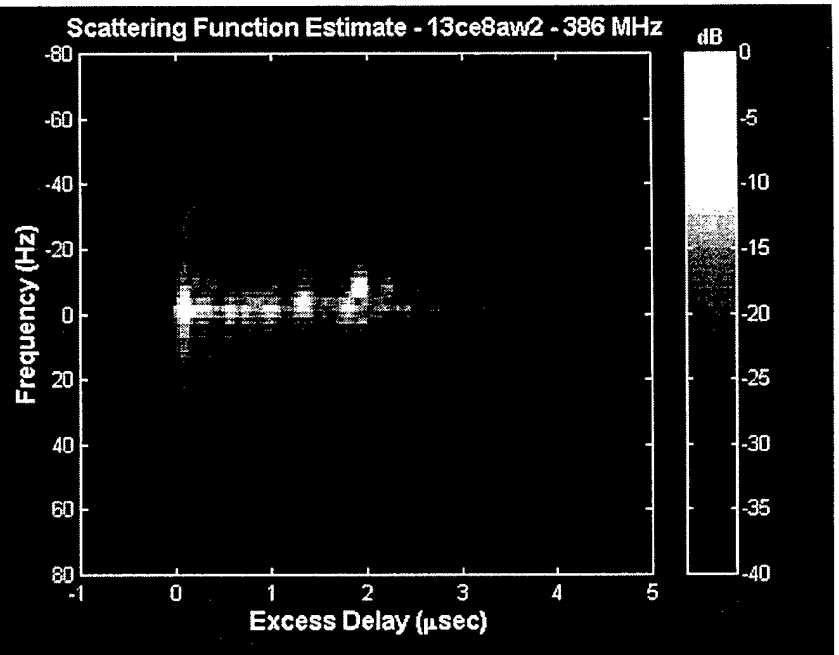
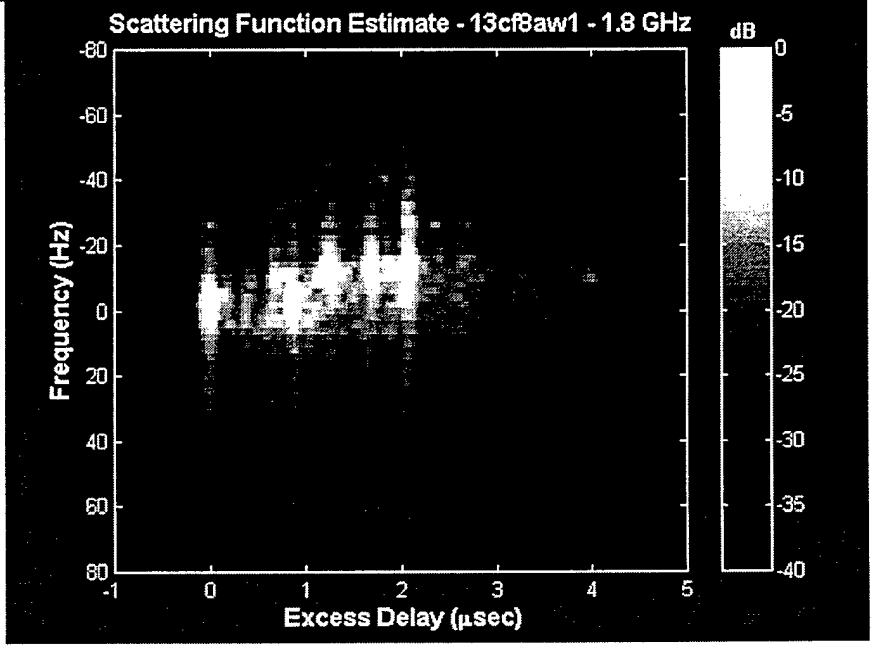
Scattering Functions - Motion







- Speed ~ 4 m/sec
- Environment: Medium/Heavy Urban
- 2 Km Distance
- Low-Low Antenna
- No Line of Sight

- Lower Frequencies exhibit more Compact Scattering Functions
- Lack of Diffraction Limits Performance on Higher Frequency

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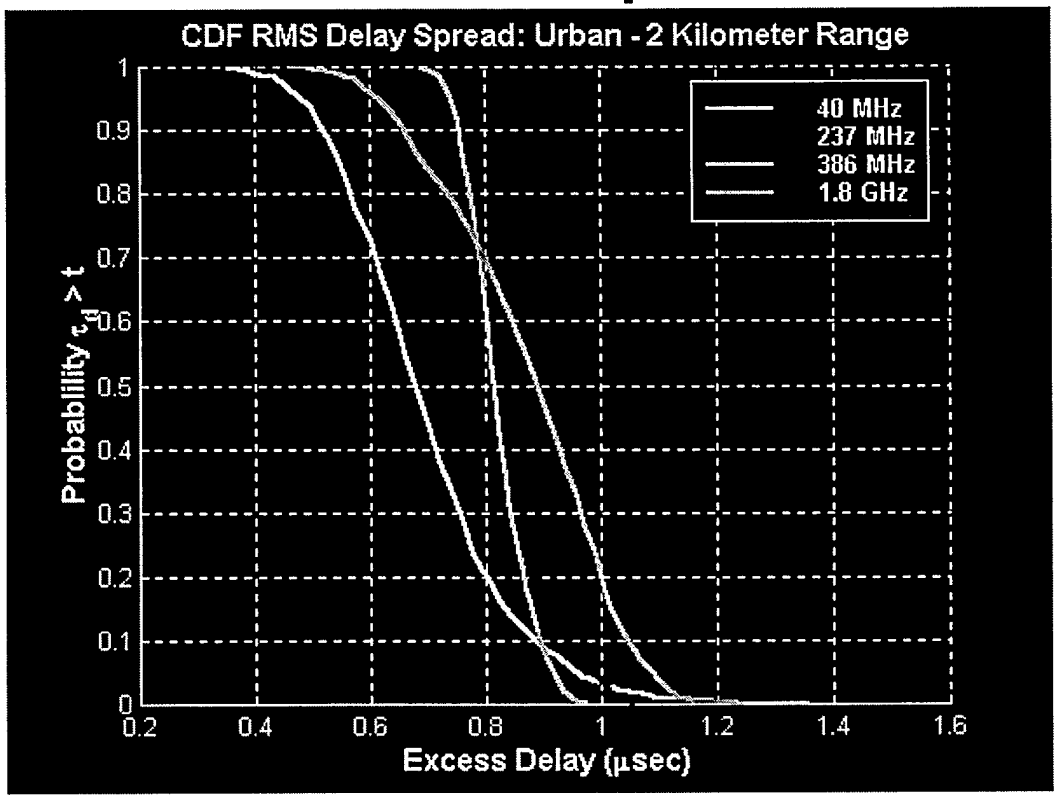
Channel Response



- ~320,000 Channel Estimates taken at 44 kHz
- Averaged to 100 Hz for Power Delay Profiles to Estimate Delay Spread (and Loss)

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Channel Loss

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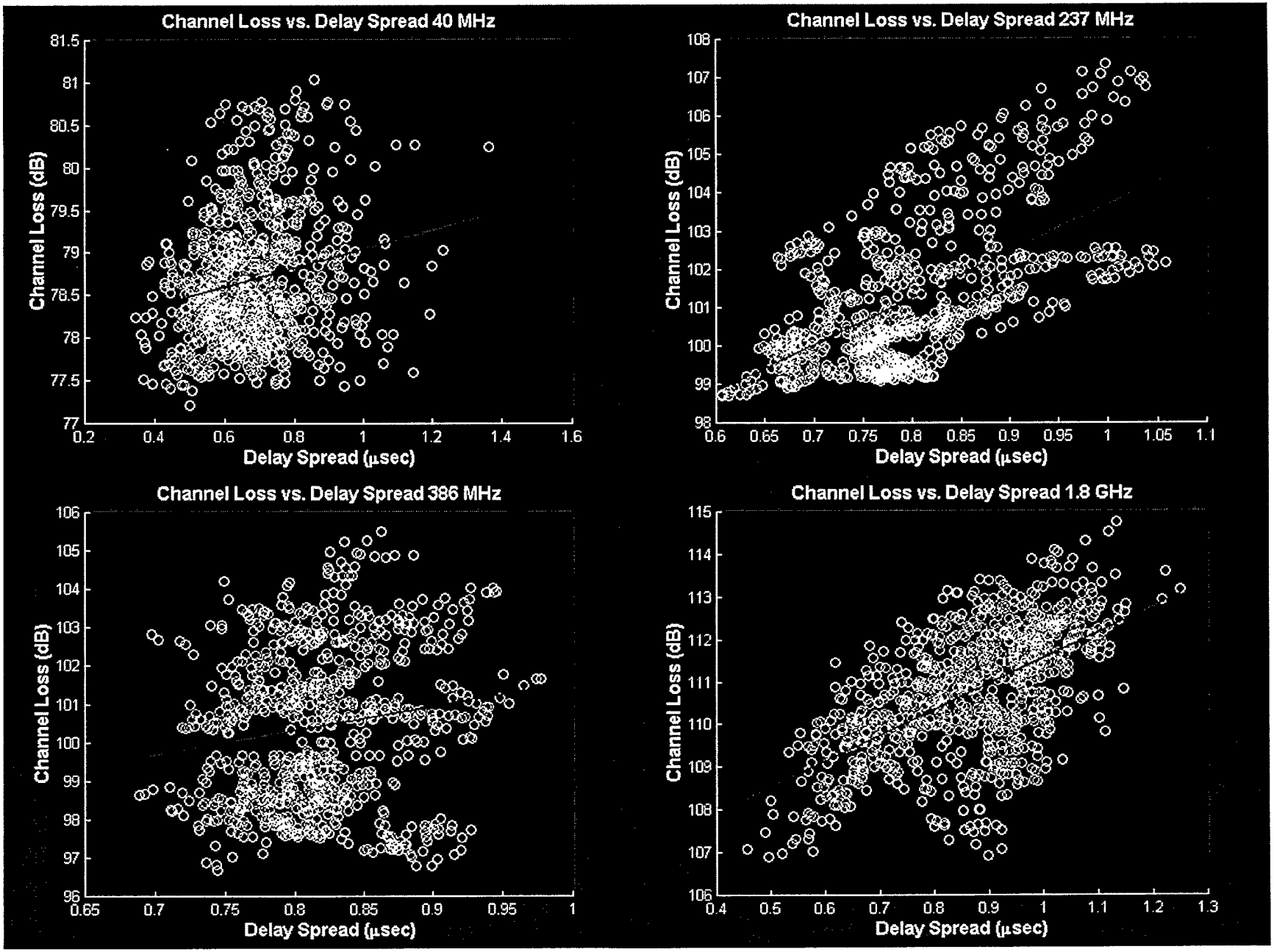

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Channel Loss

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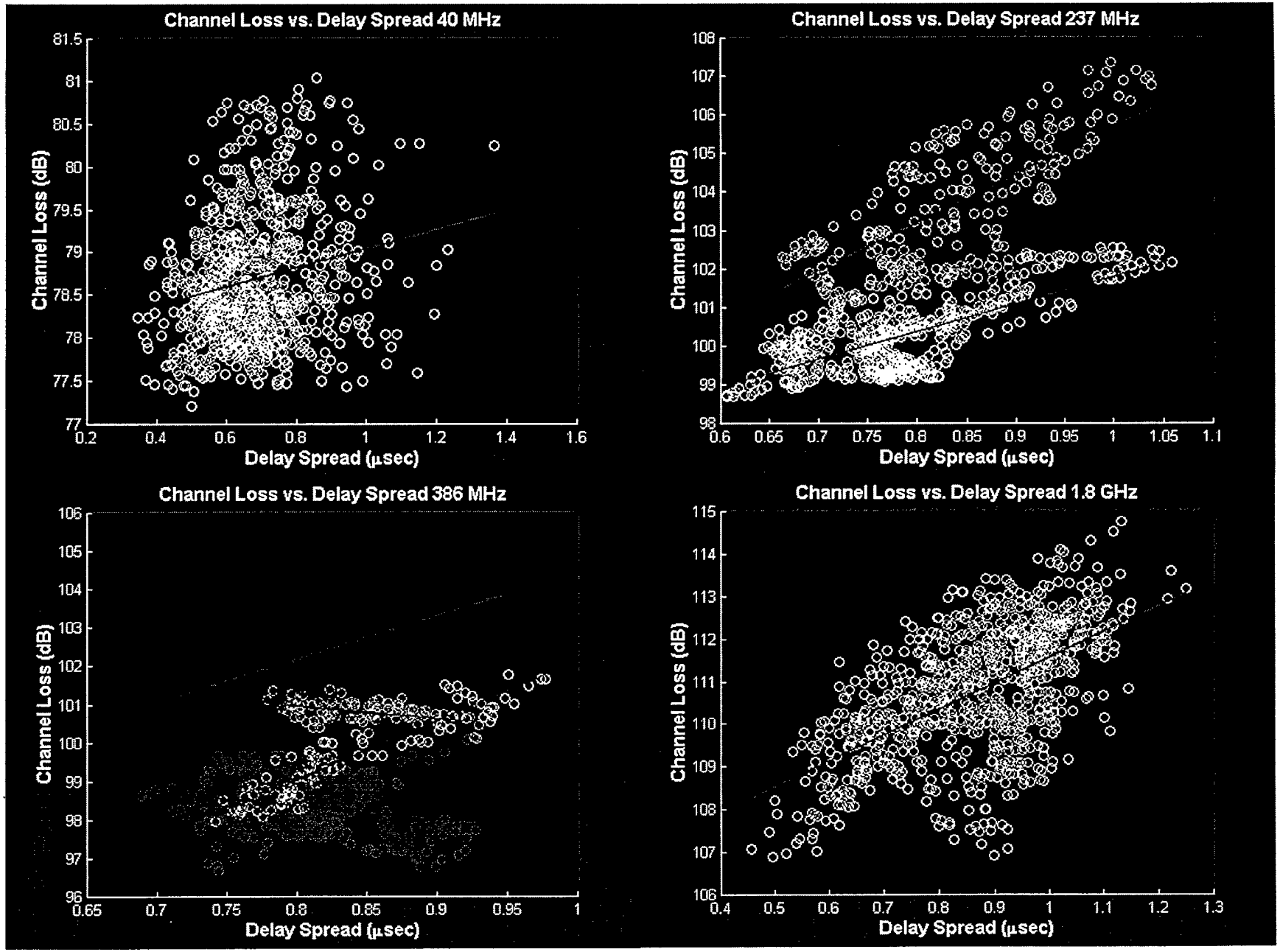

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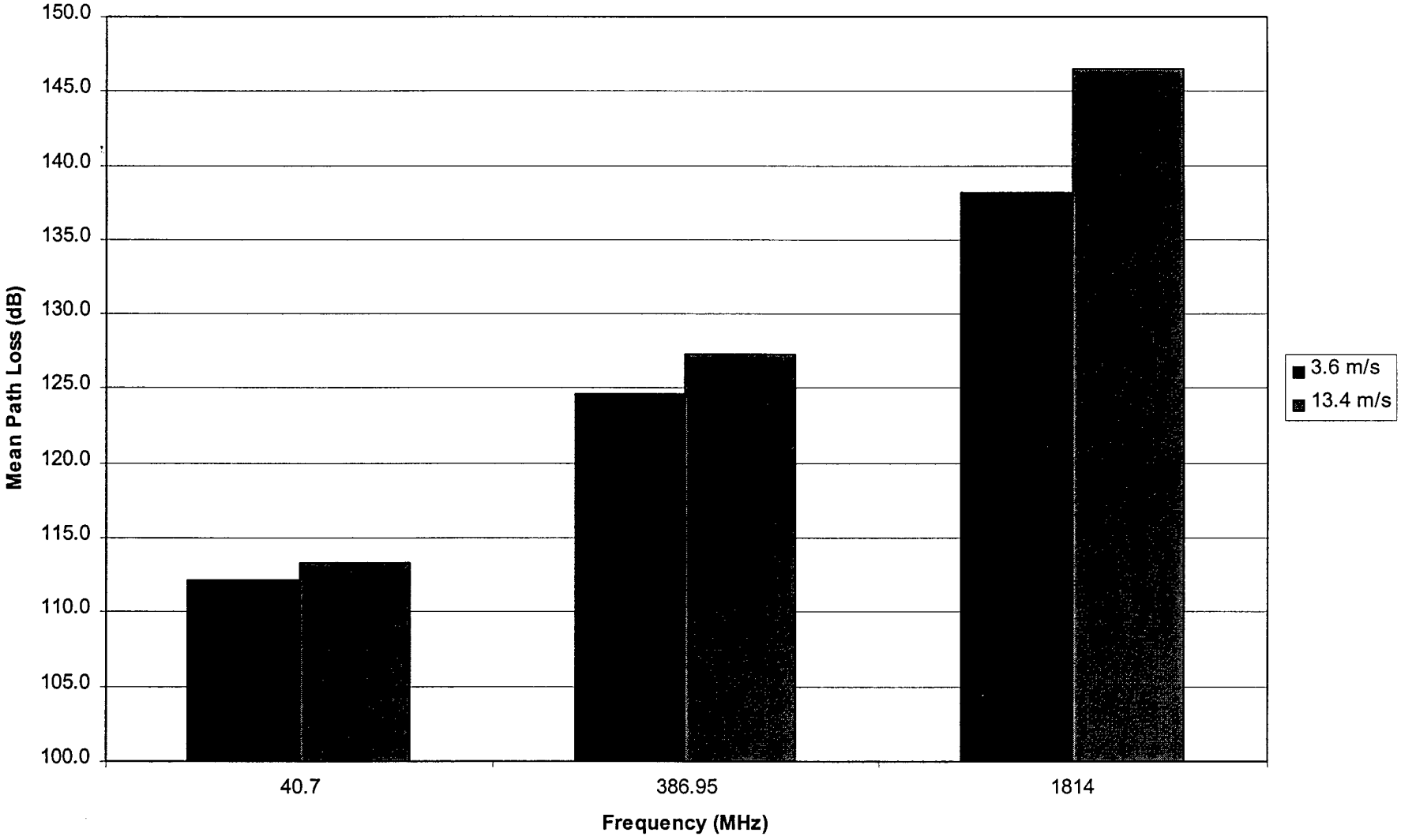
Urban Path Loss

Urban Environment, (Ch. 13; HMMWV Motion)



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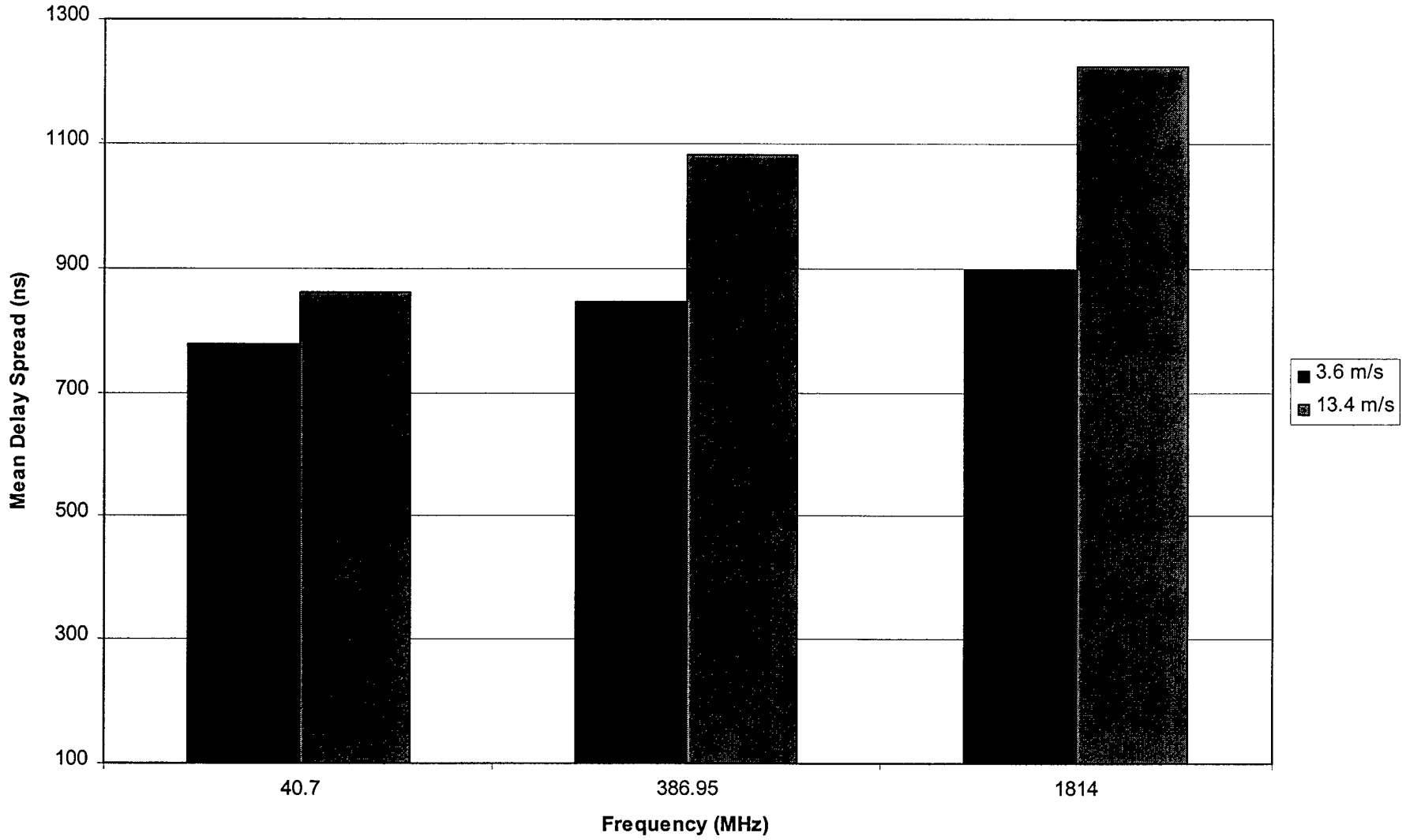
Urban Delay Spread

Urban Environment, (Ch. 13; HMMWV Motion)



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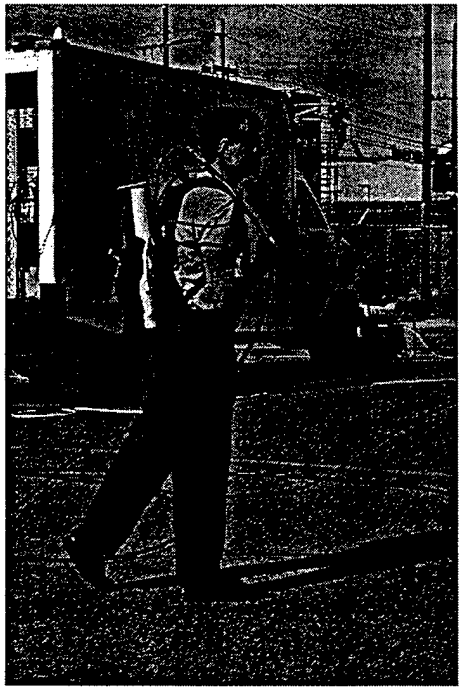
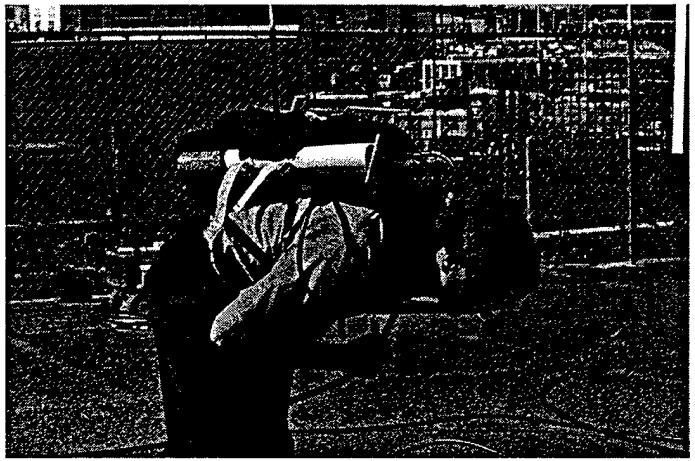
Soldier Mount





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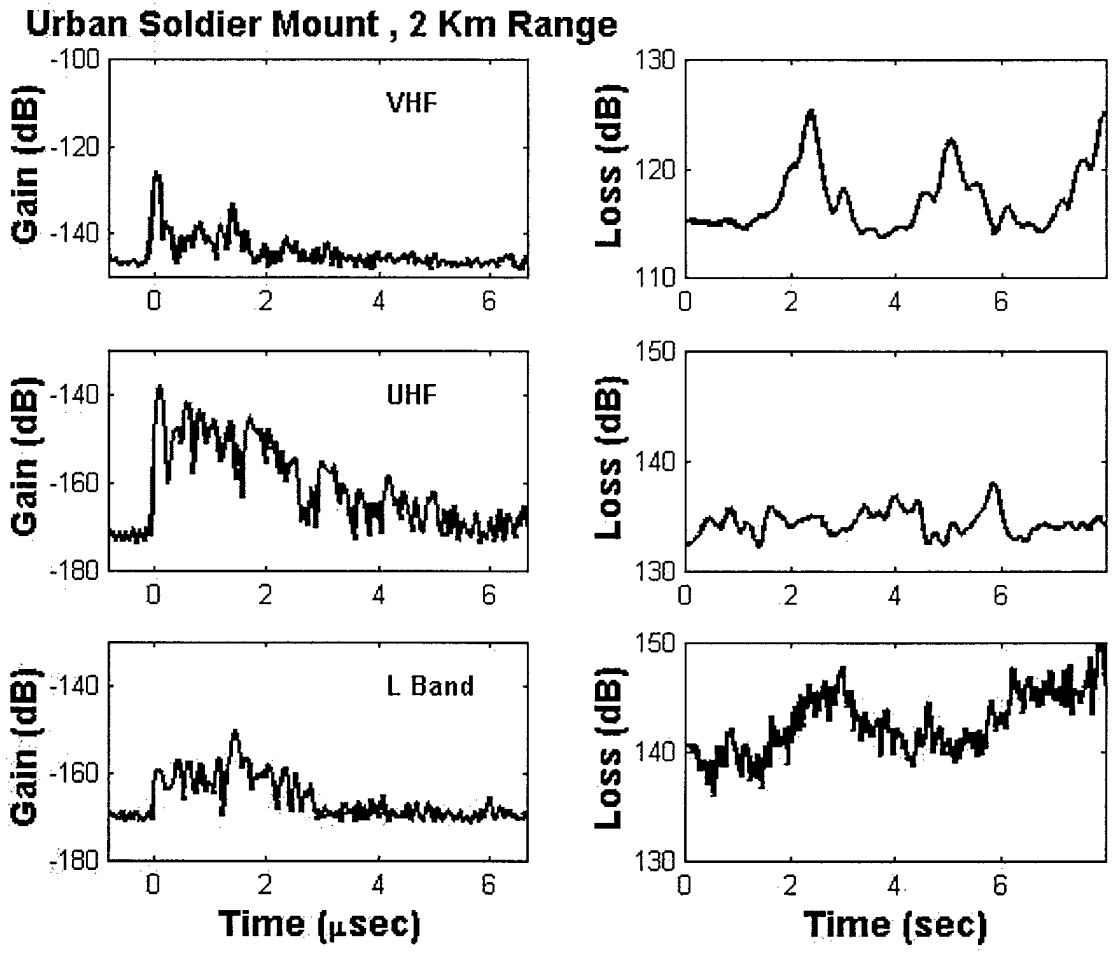
Soldier Mount



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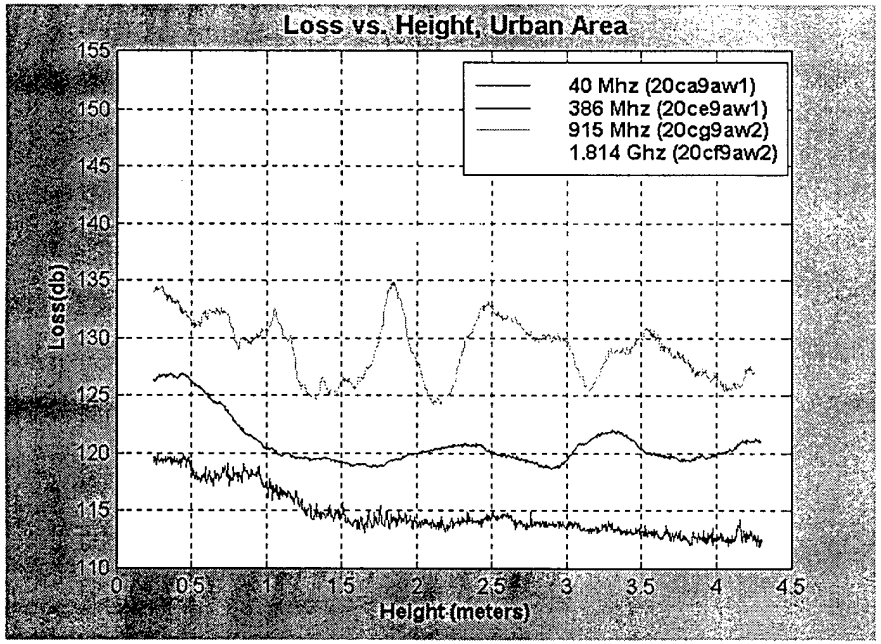
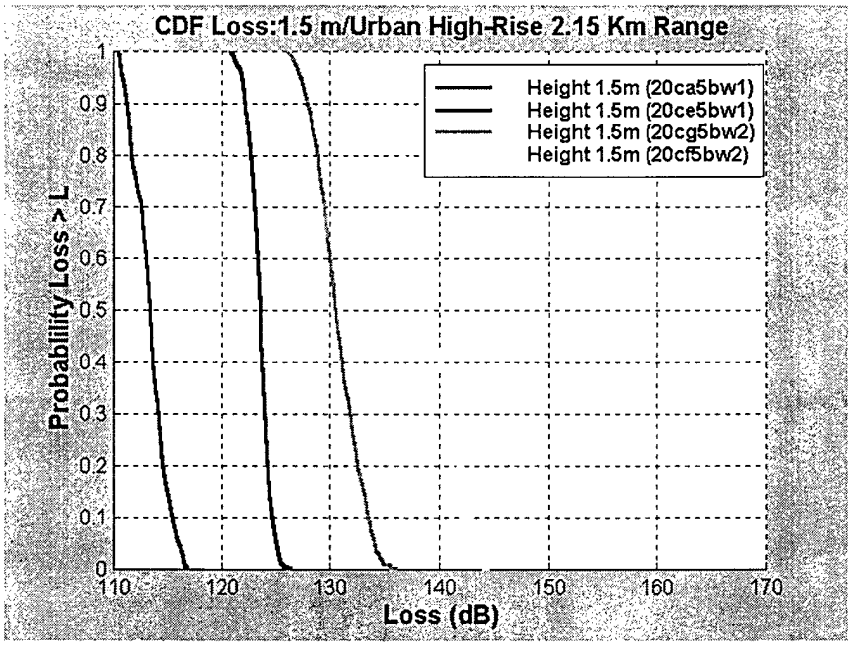
Urban Path Loss vs. Height





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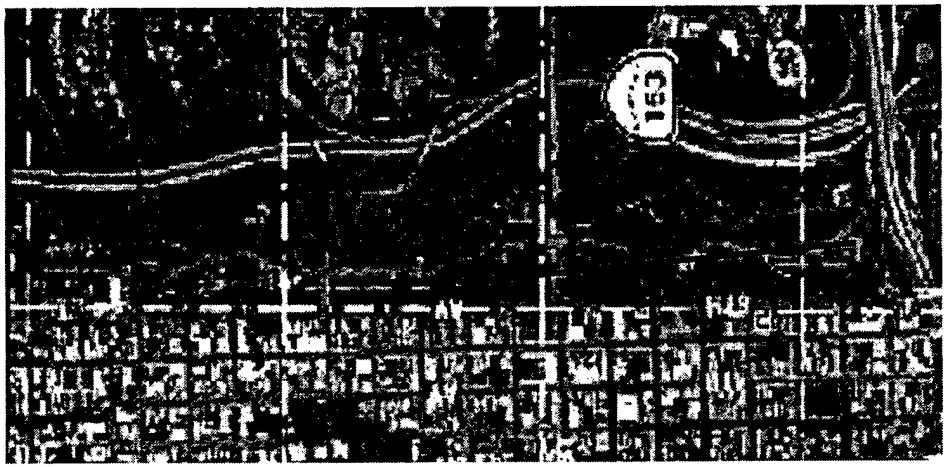
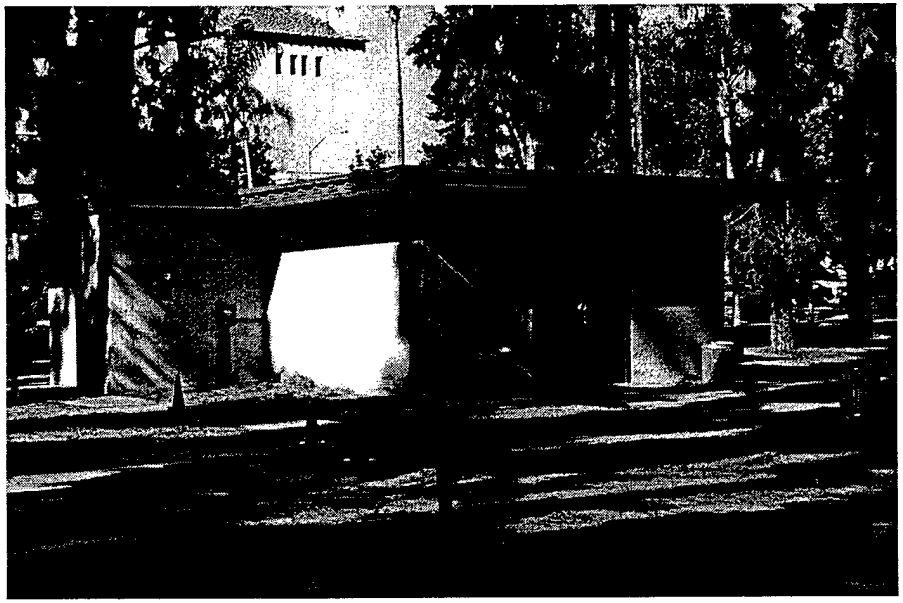
Balboa Park, Block Building





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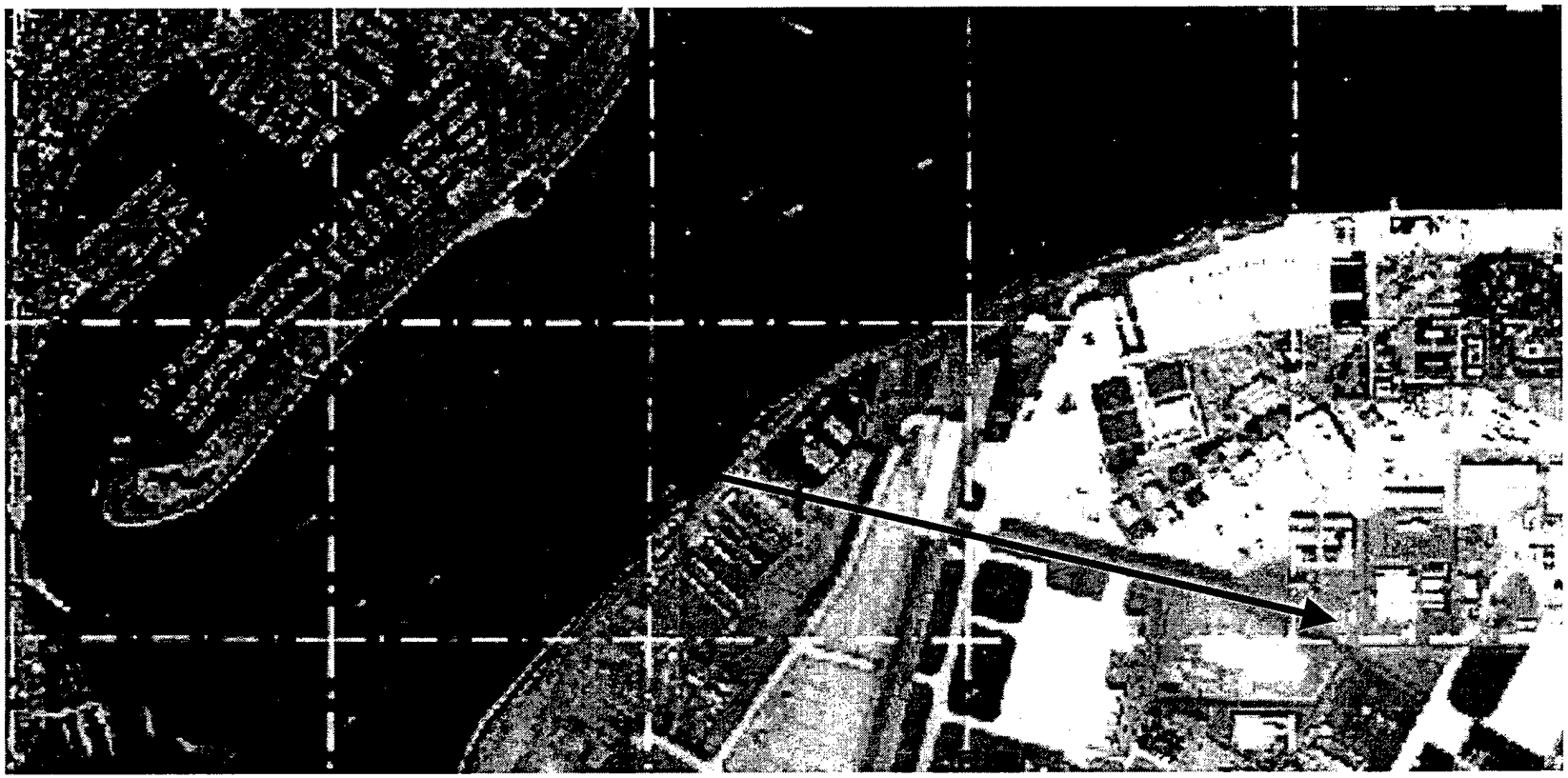
North Island - Metal Building



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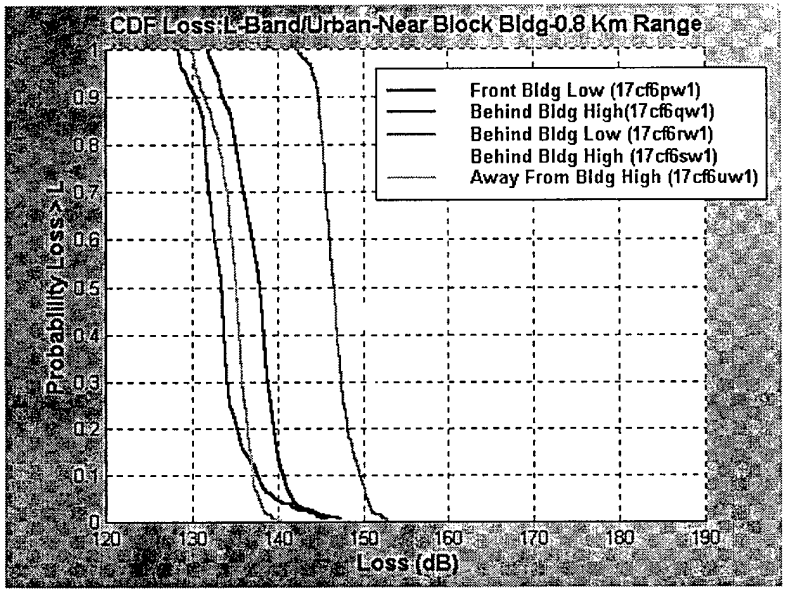

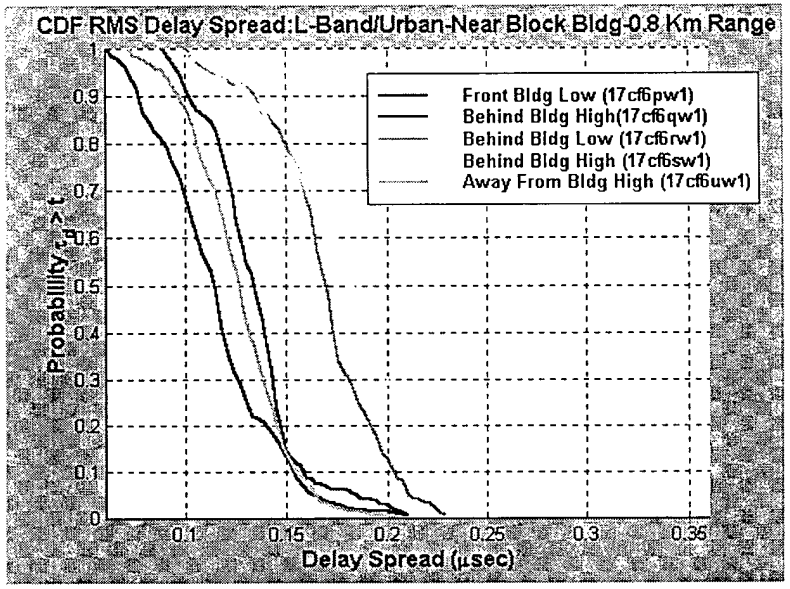

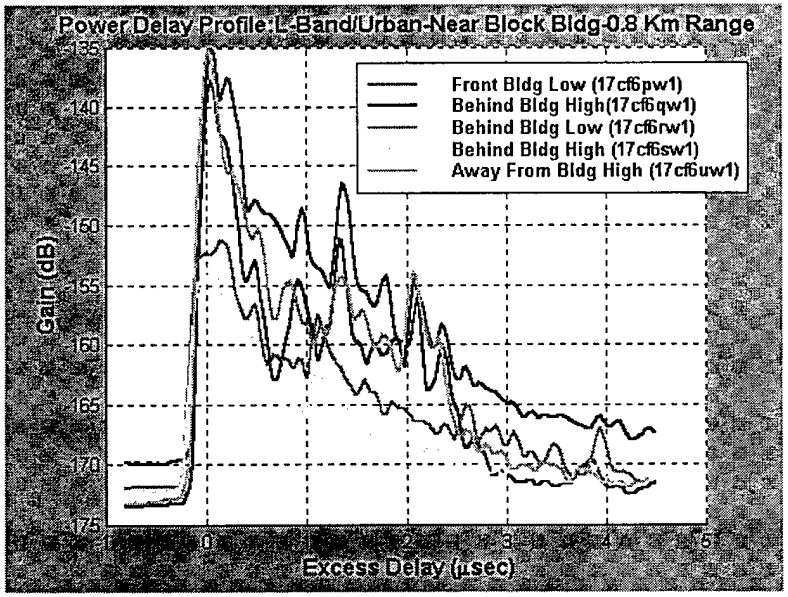

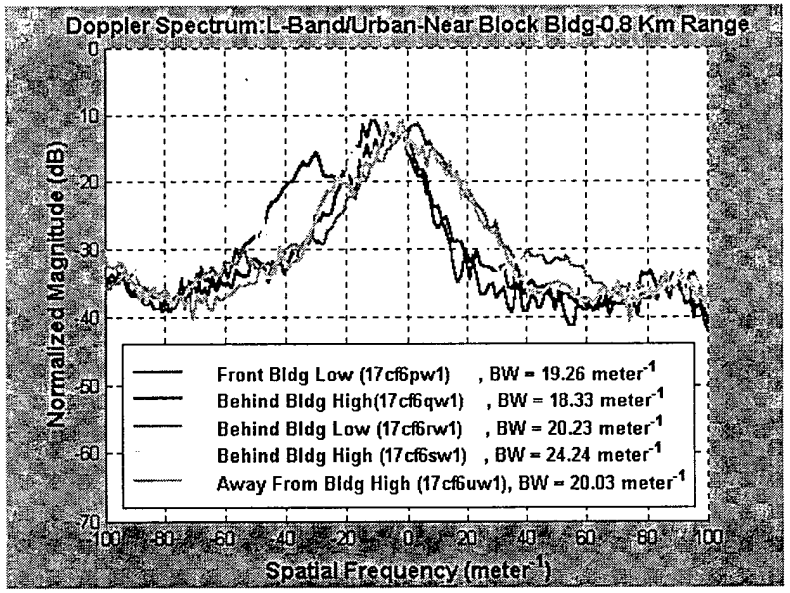

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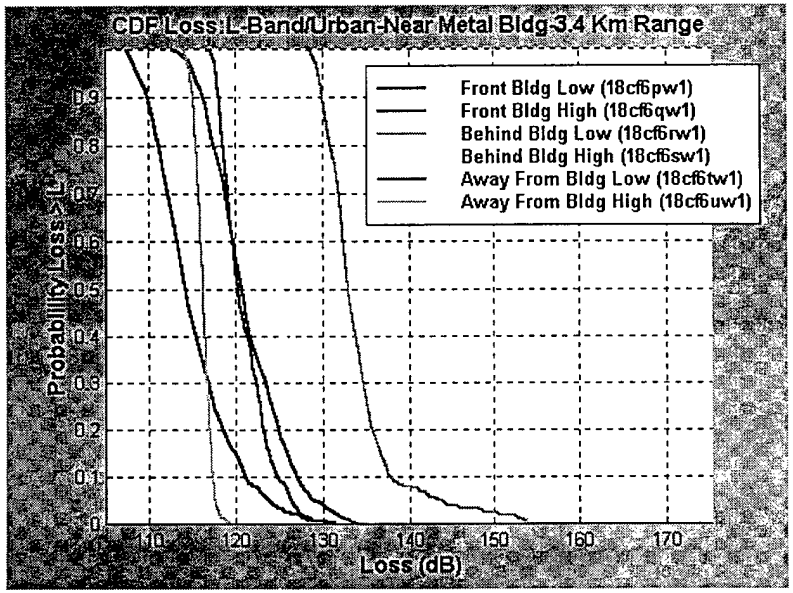

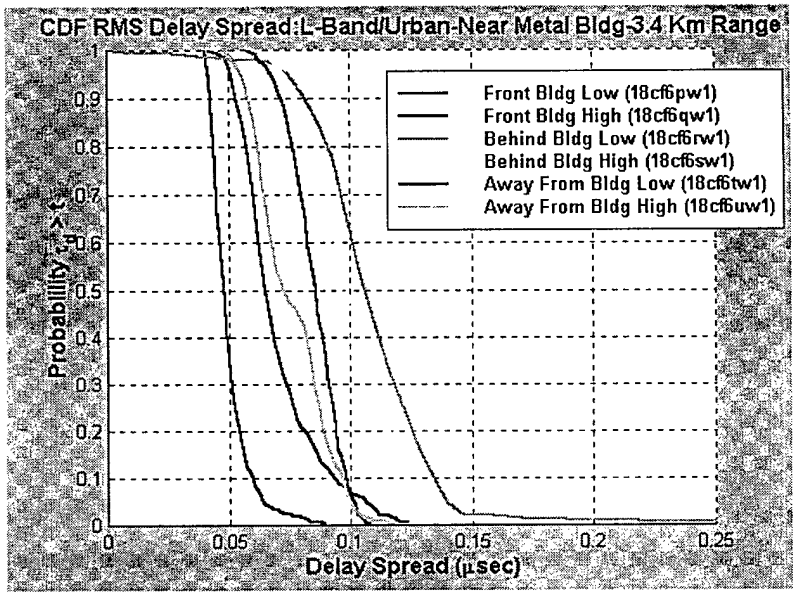

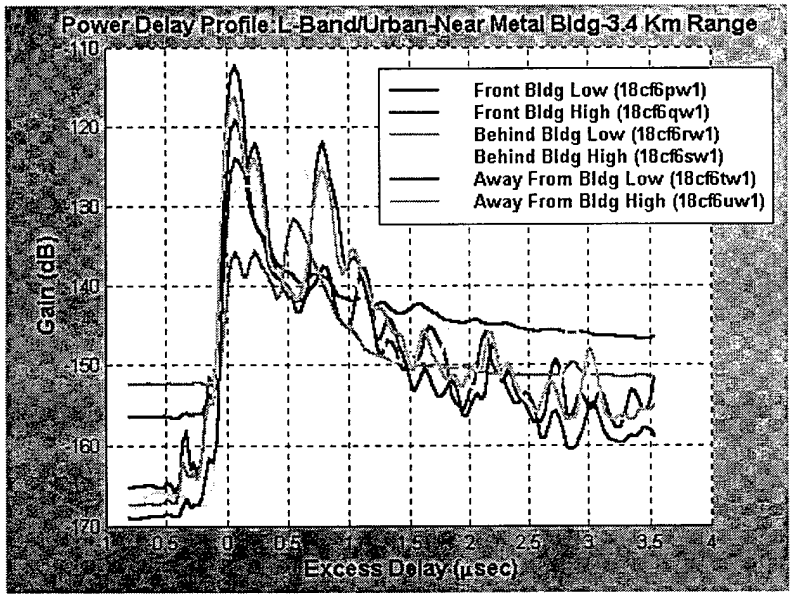

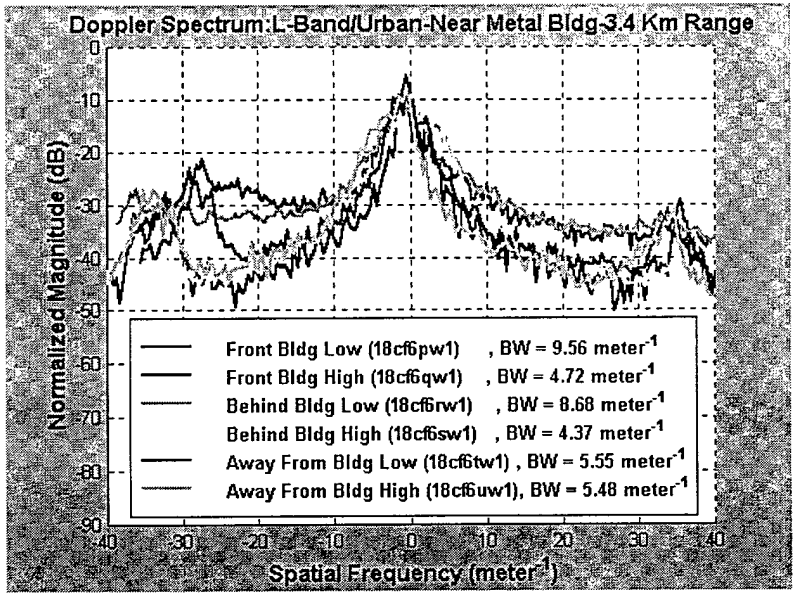

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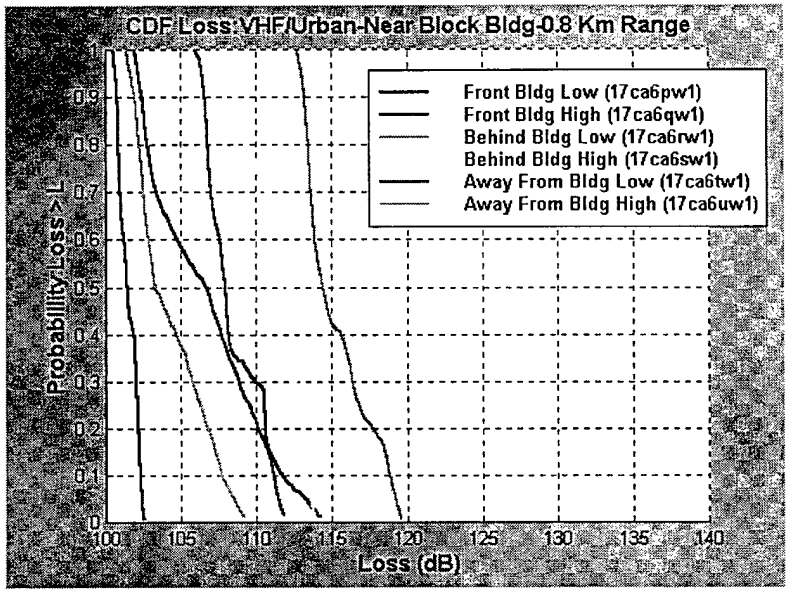

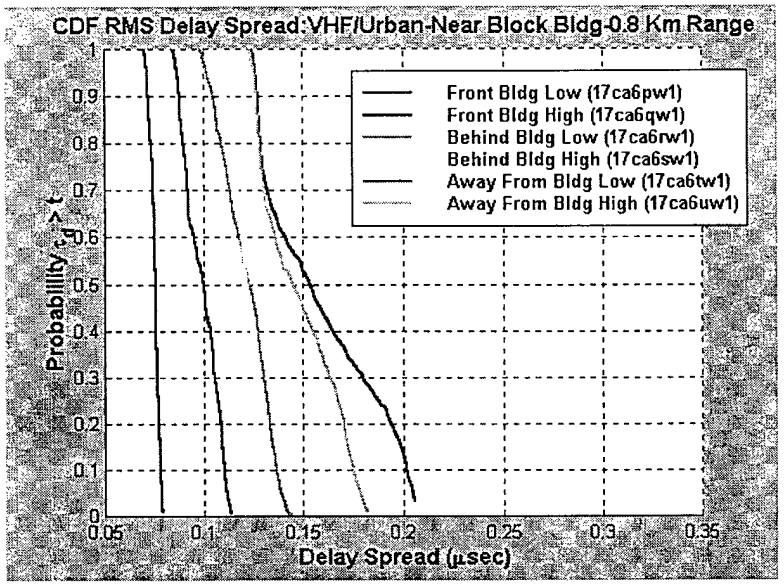

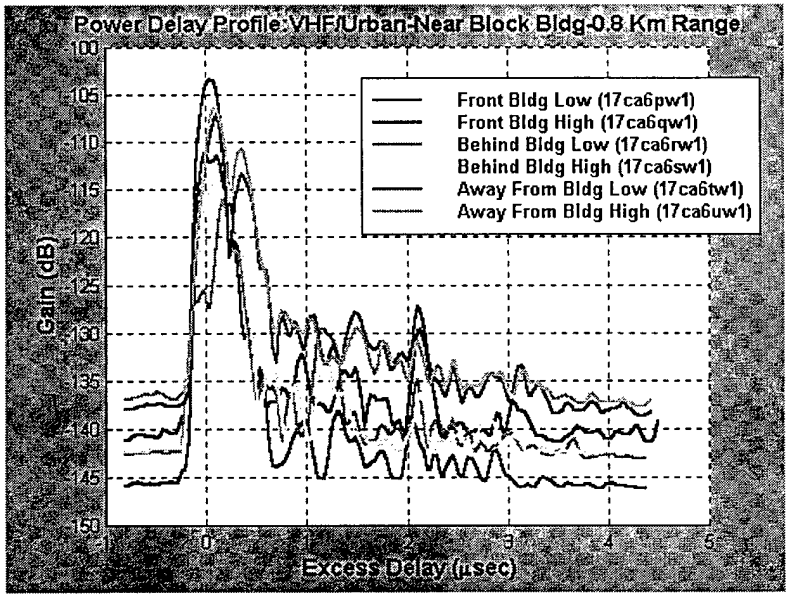

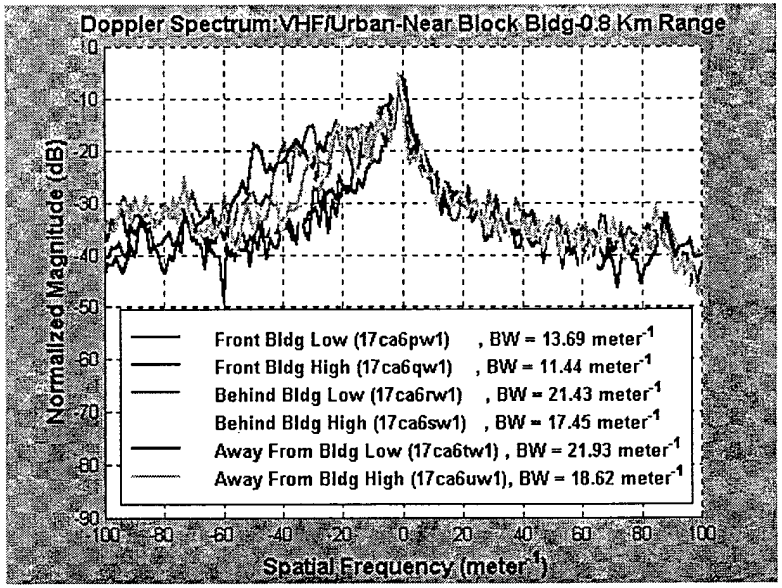

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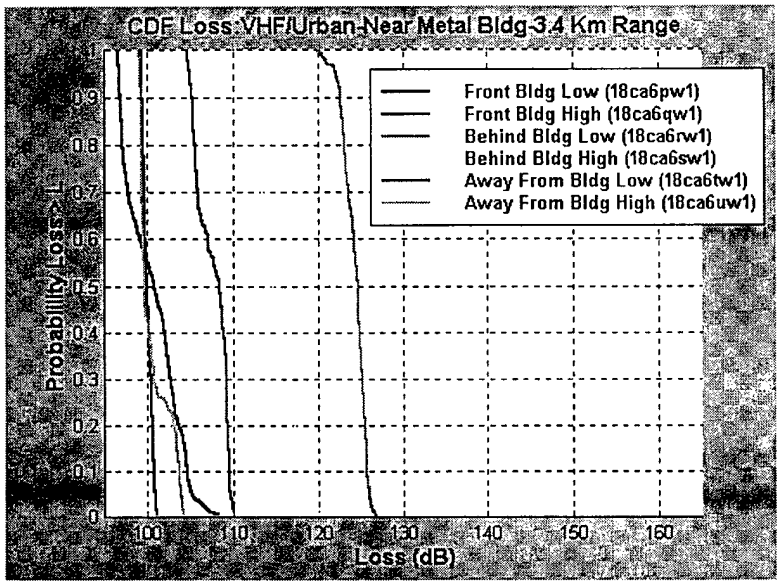

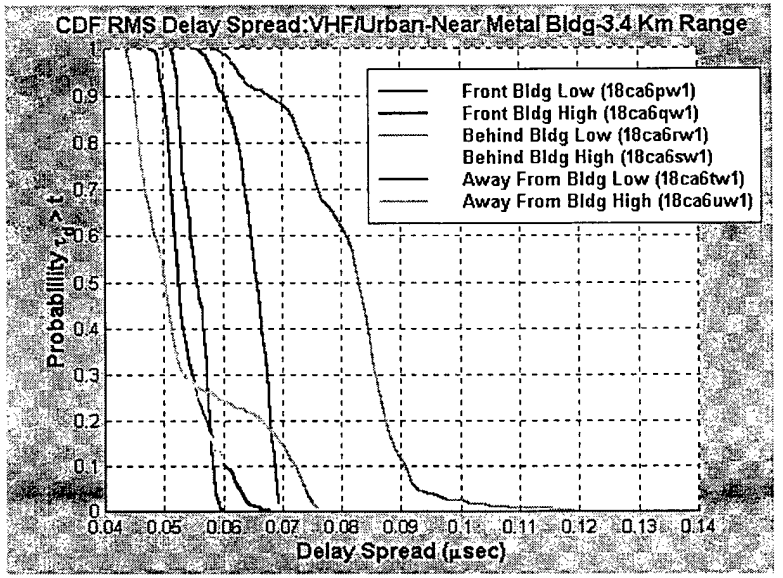

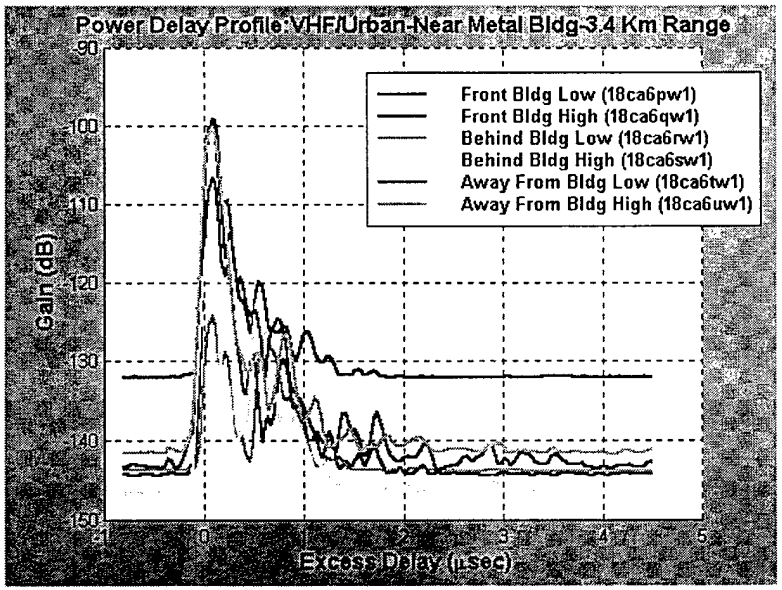

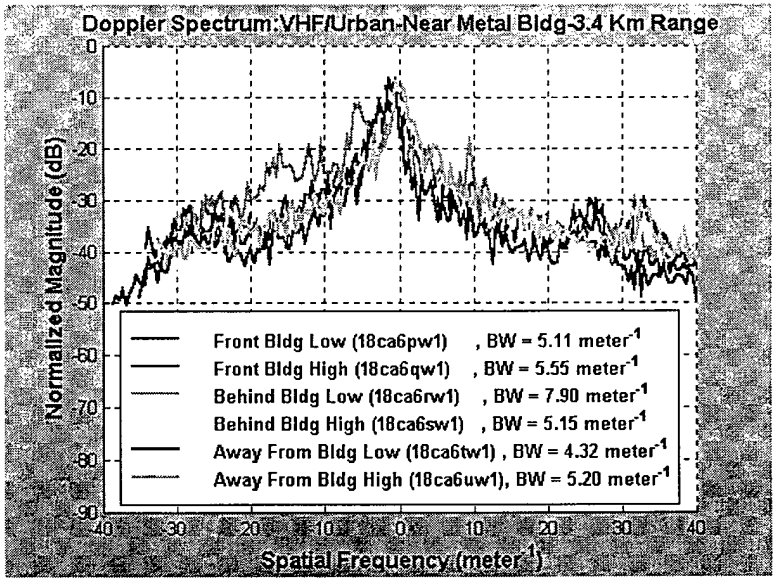

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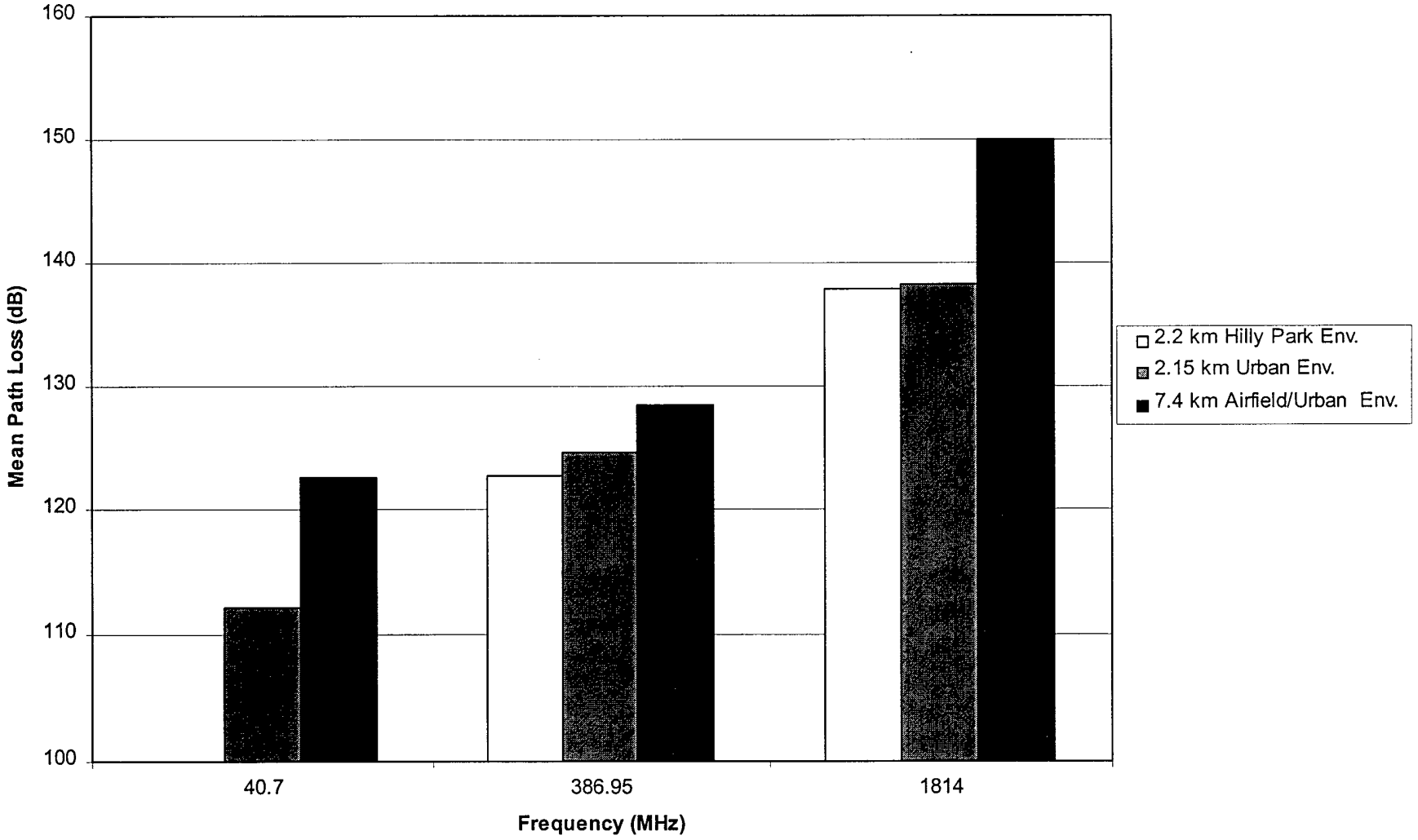
Path Loss vs. Frequency & Environment

DARPA

Various Environments (Ch 16, 13, 19; 3.6 m/s HMMWV Motion)



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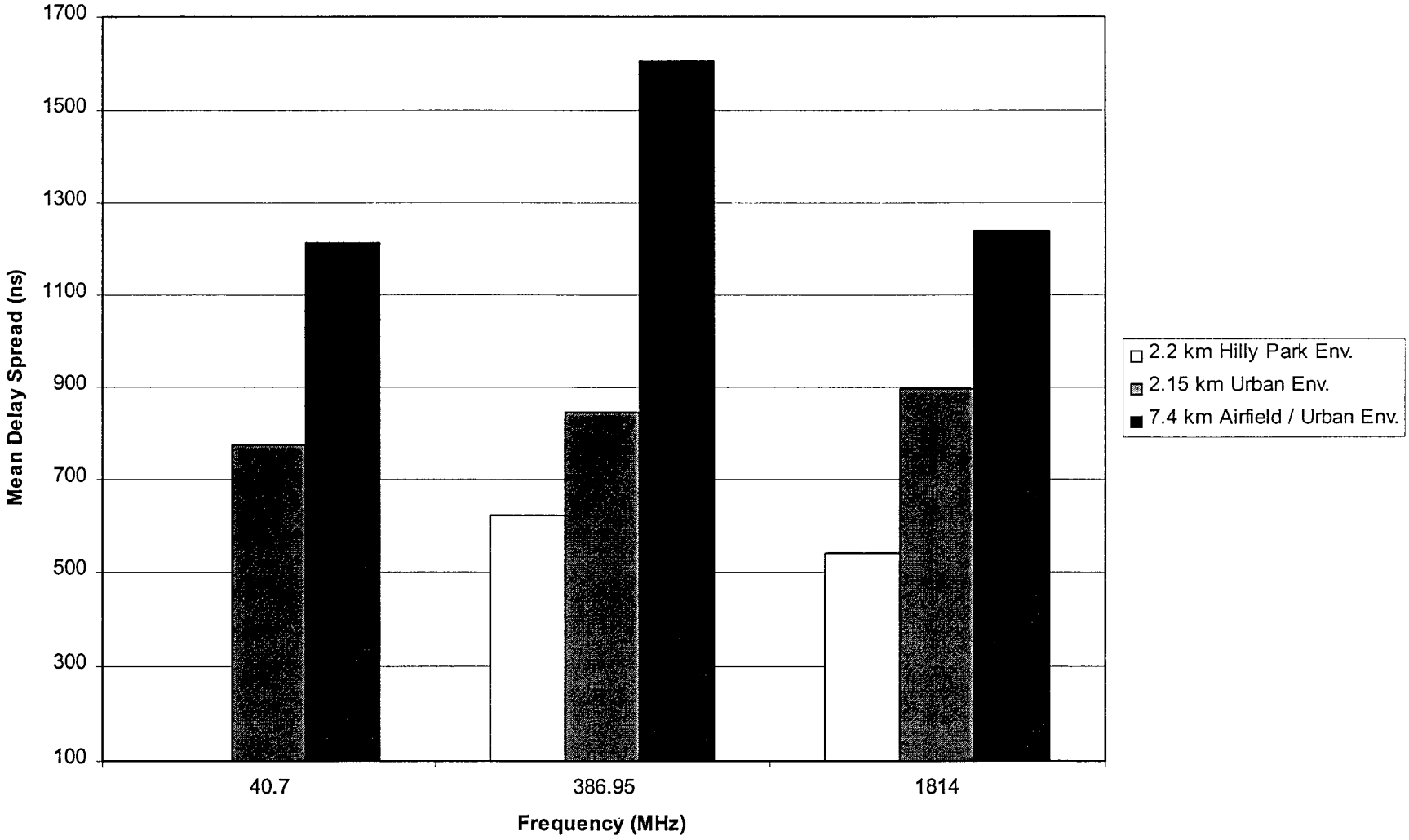
Delay Spread vs. Frequency & Environment

DARPA

Various Environments (Ch 16, 13, 19; 3.6 m/s HMMWV Motion)



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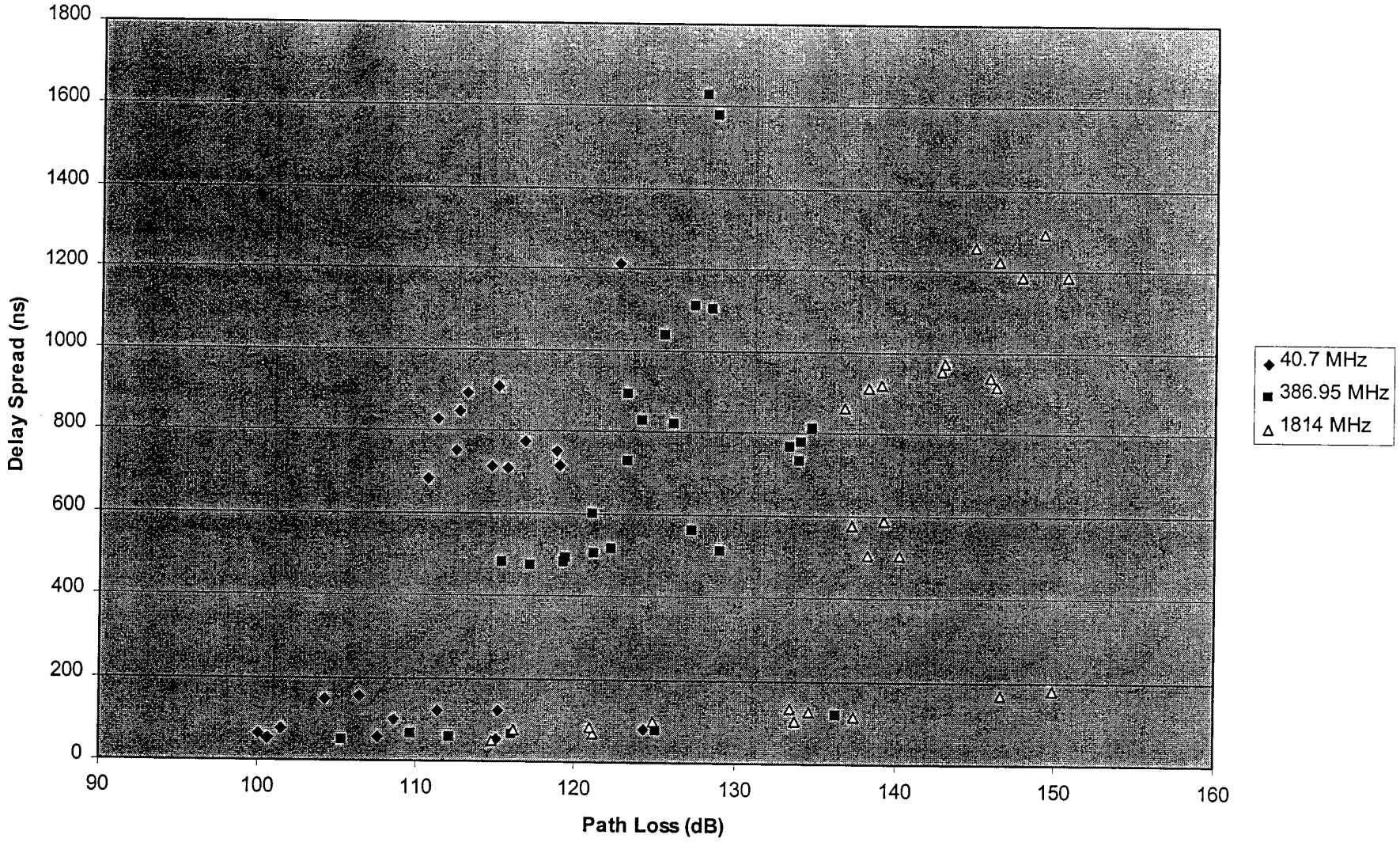
PL-DS Scatter Plot

(All Cases Combined)



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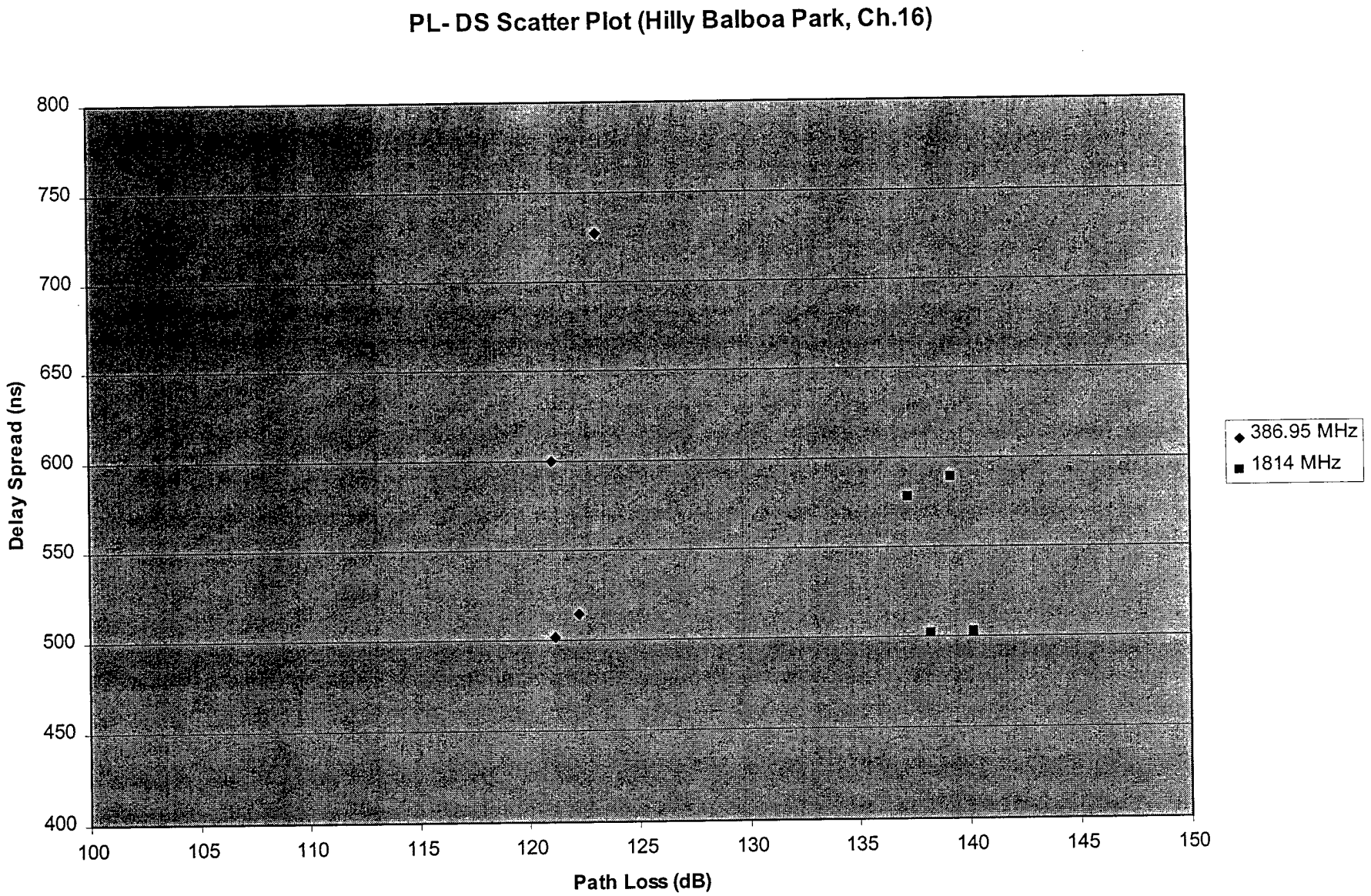
Balboa Park Hills/Trees (2.2 Km)



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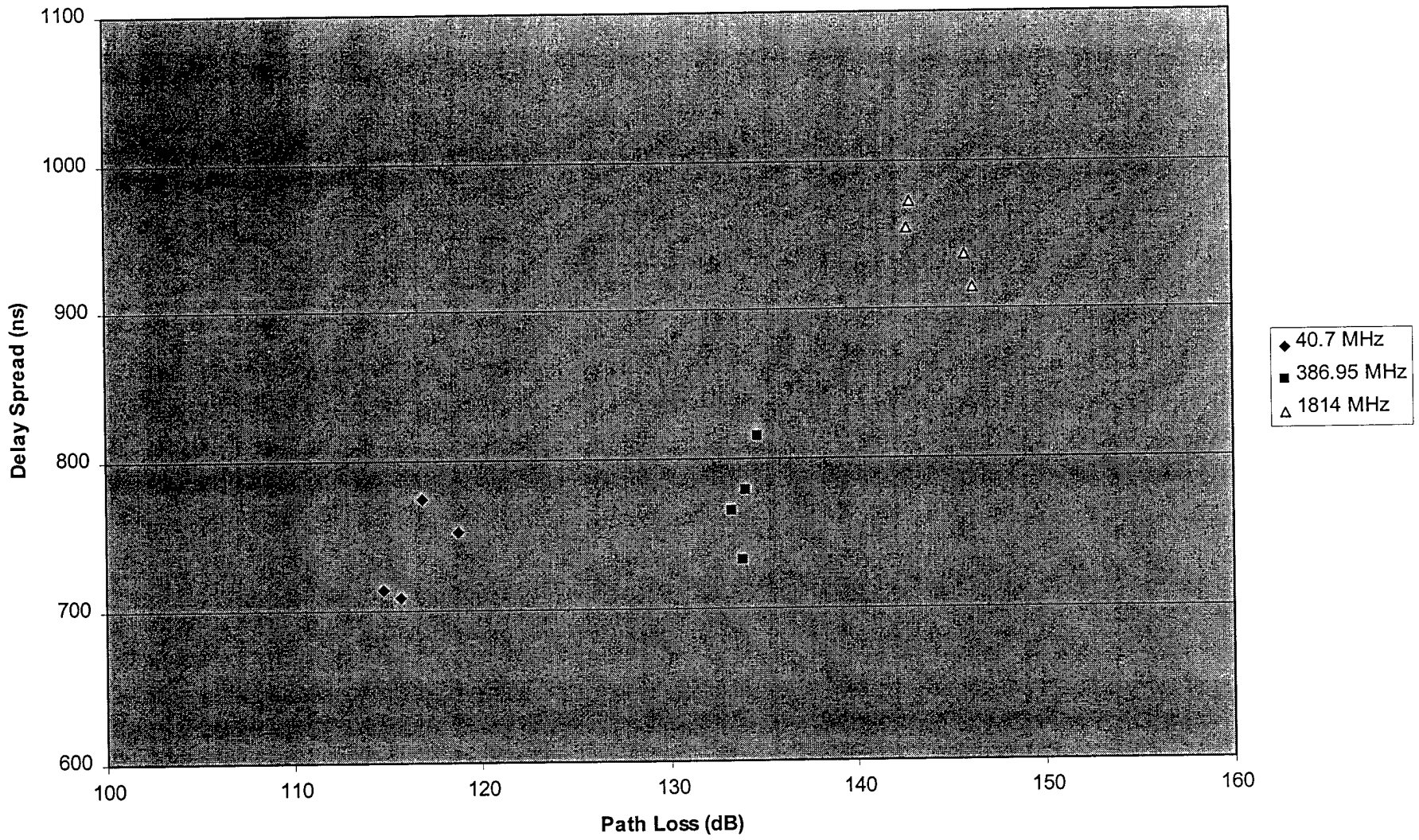
Urban Soldier Mount (2.1 Km)

PL - DS Scatter Plot (Soldier Motion, Ch. 13 & 20)



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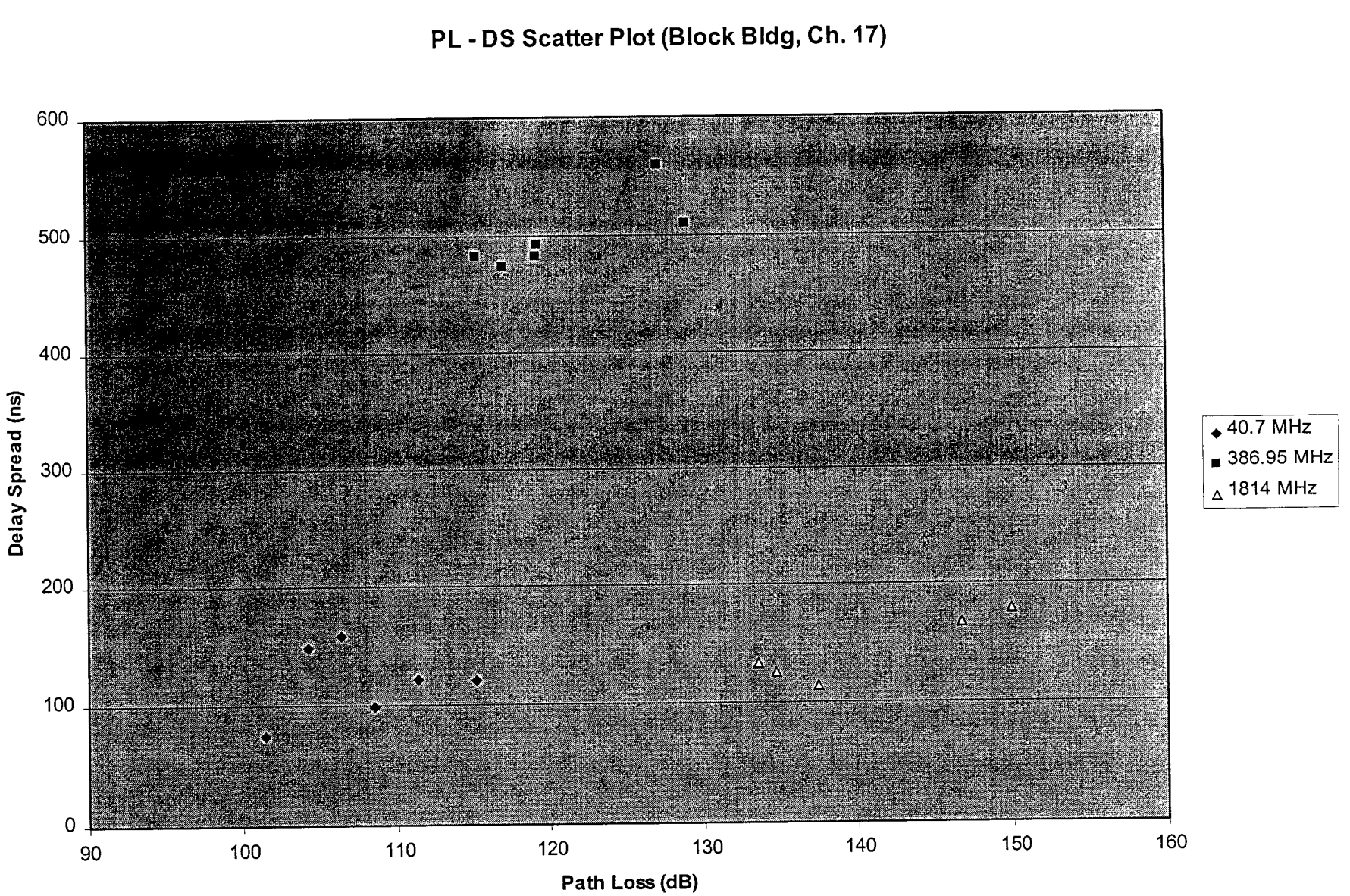
Balboa Park (0.8 Km)



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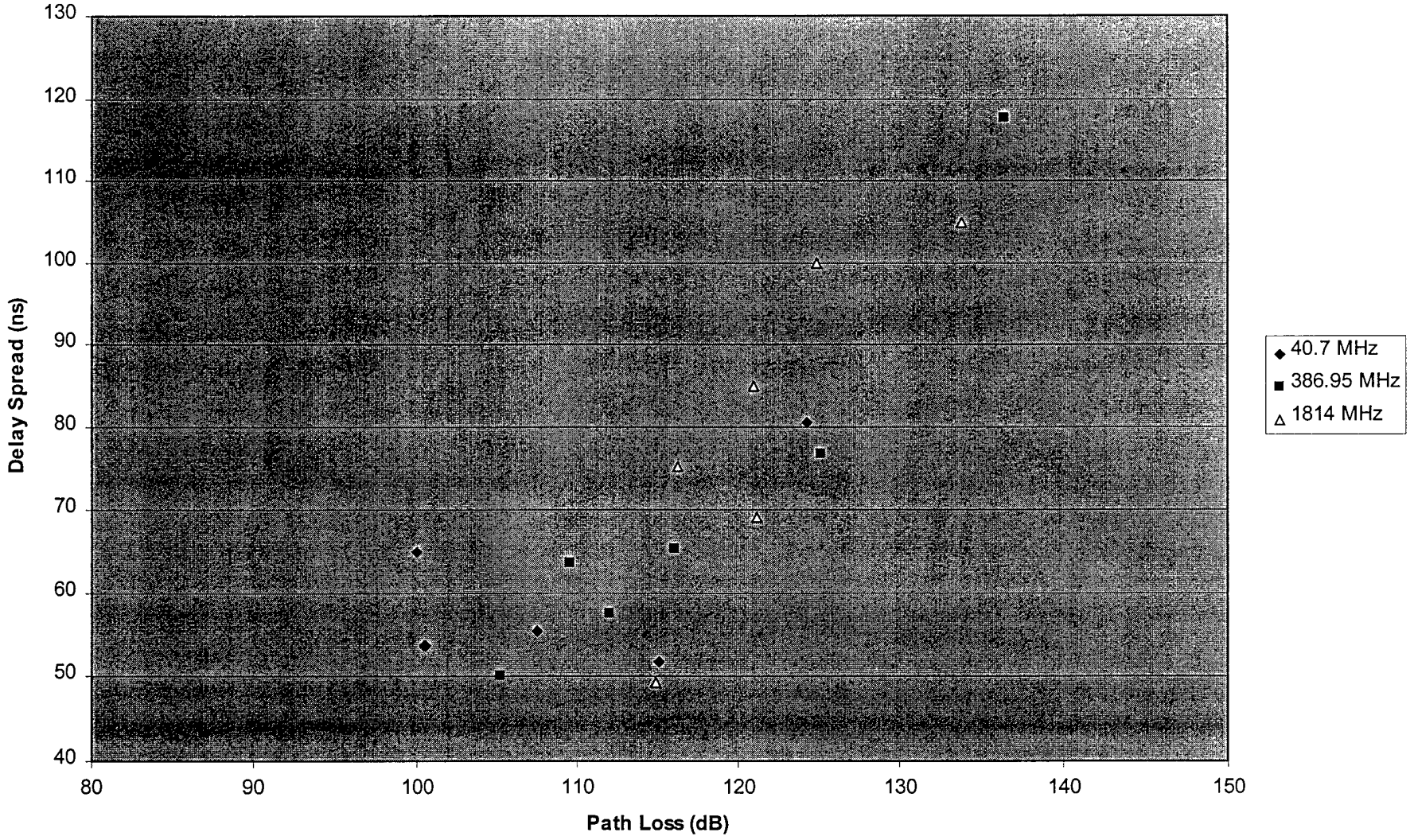
Airfield (3.4 Km)

PL - DS Scatter Plot (Near Metal Bldg, Ch. 18)



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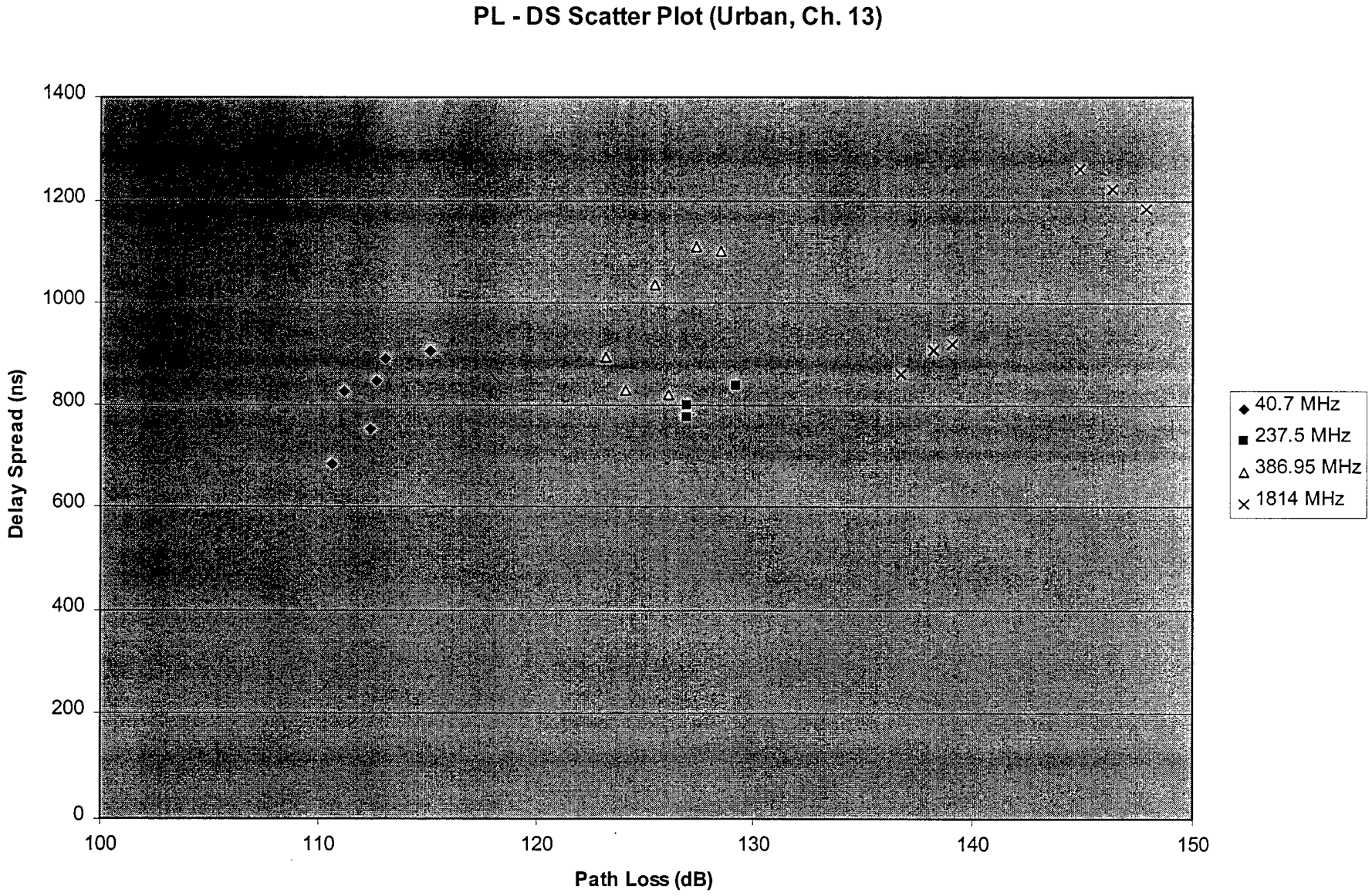
Urban HMMWV Mount (2.1 Km)



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Outline

- Measurement Goals and Capabilities
- Multipath Tutorial
- Sample Results
  - Urban Channel
    - HMMWV Motion
    - Human Mount w/Motion
    - Various Antenna Heights
  - Many Channels
    - Path Loss vs. Delay Spread

» Model Comparisons

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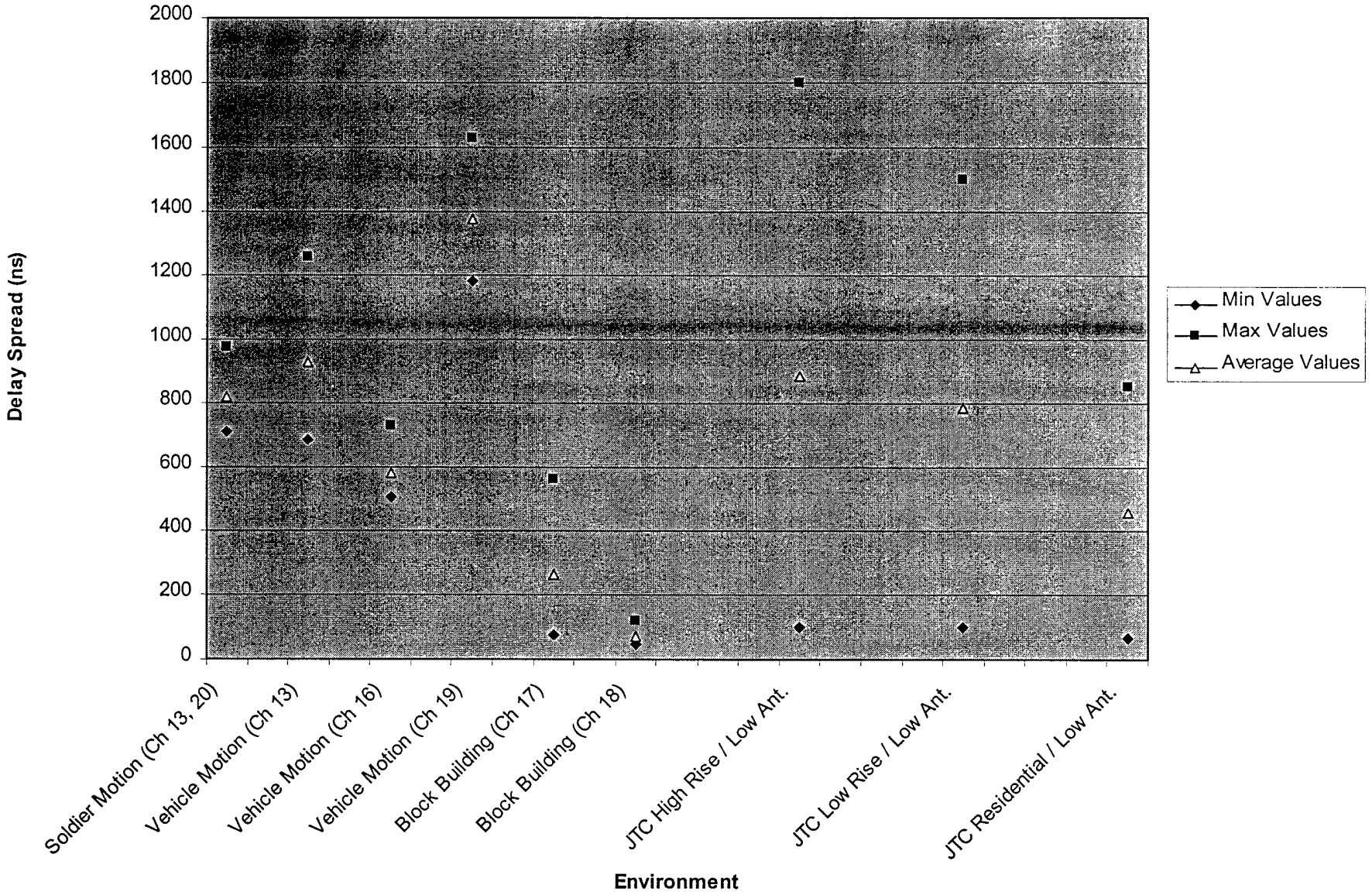
JTC Model Comparison



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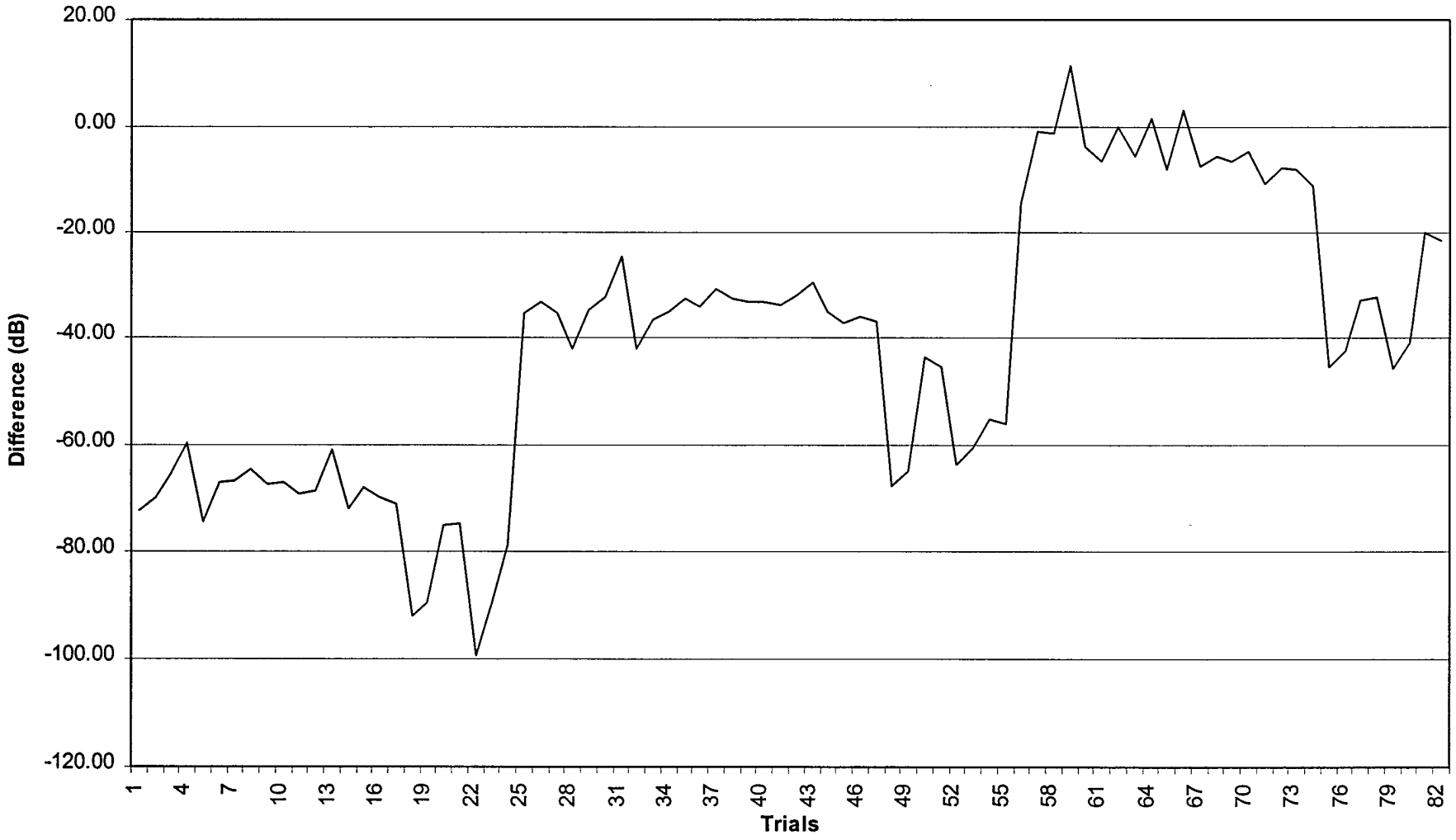
JTC Model Comparison

Measured - JTC (dB)
Sorted by Frequency/Distance/Channel



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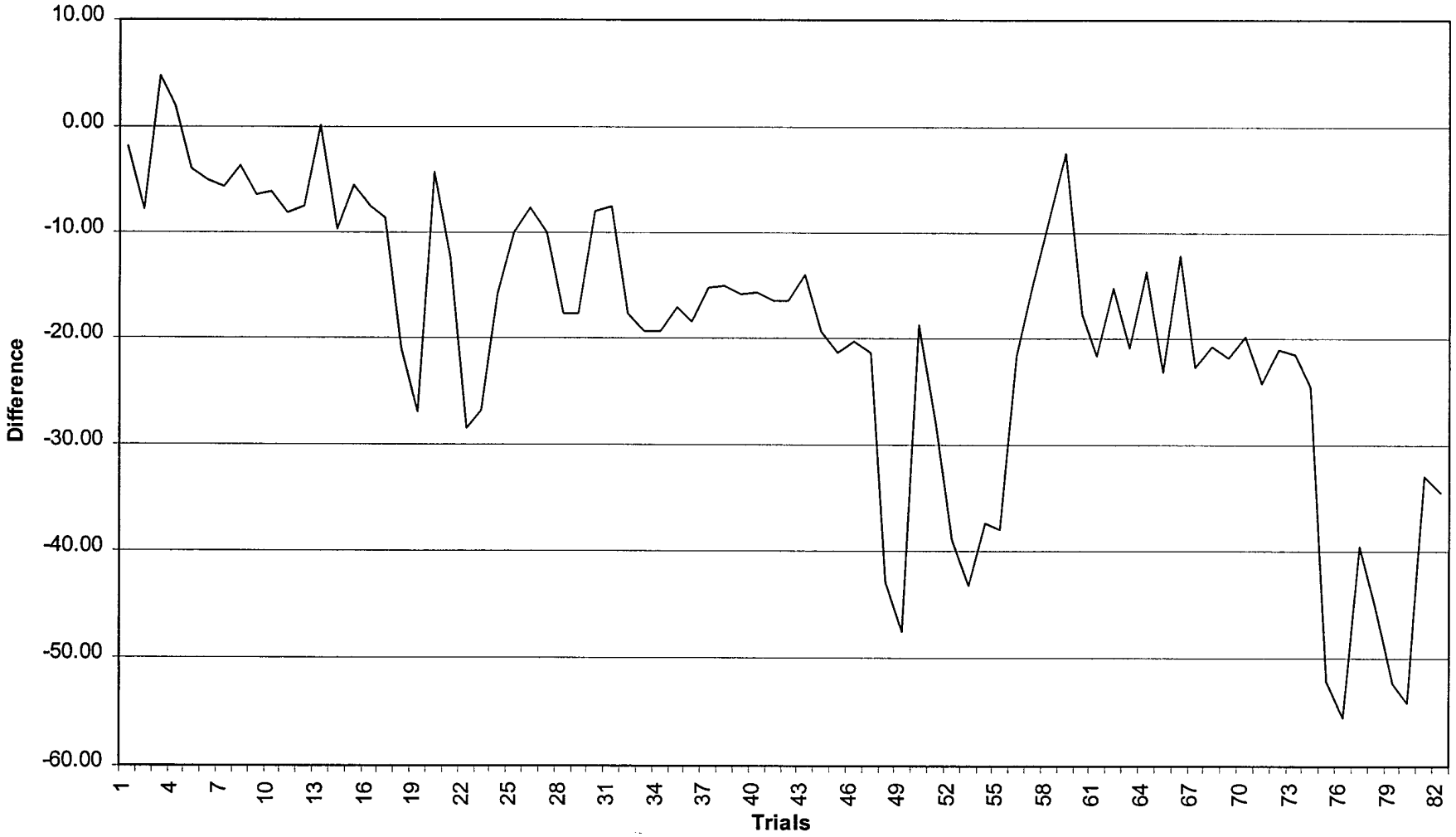
Hata Model Comparison

Measured - HATA (dB)
Sorted by Frequency/Distance/Channel